Moldex3D

CAE模流分析在变模温技术之应用

刘文斌 大中華區技術總監

CoreTech System Co., Ltd
www.moldex3D.com

Plastic Applications

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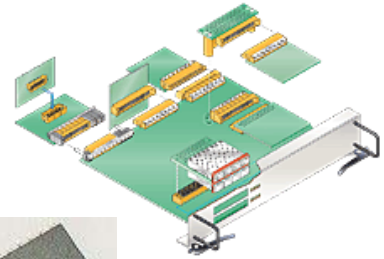

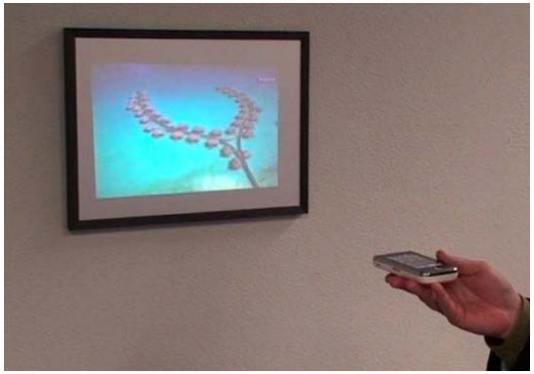

Common Problems and Challenges

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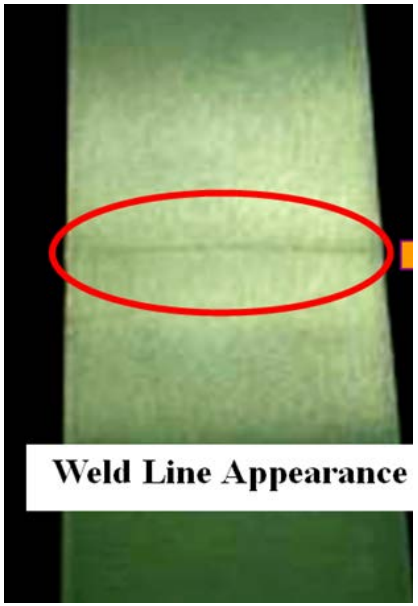
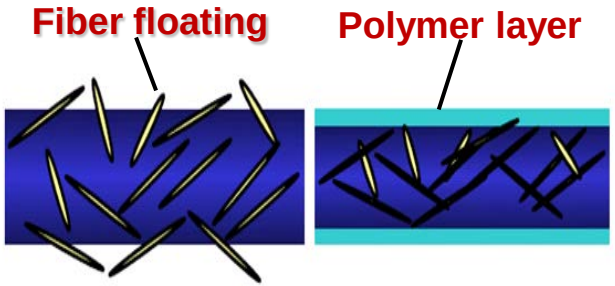
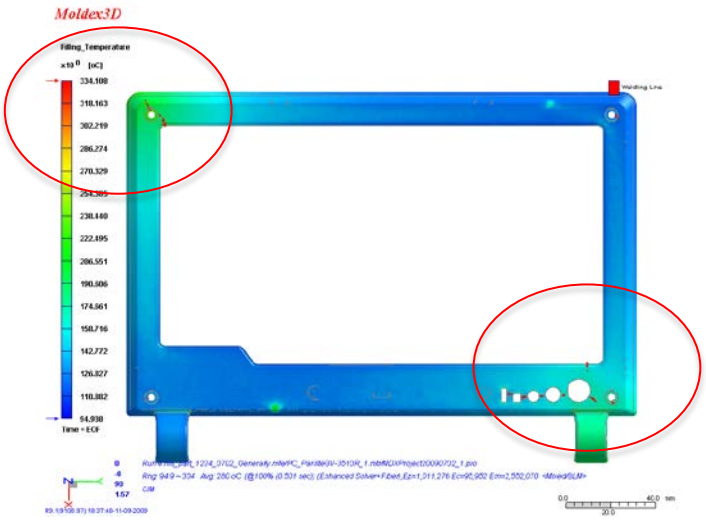
- For general injection molding
  - Weld line
  - Flow mark
  - Surface gross
  - Fiber floating
- For micro-injection molding
  - Poor replication for tiny features
- Many others





Common Problems and Challenges

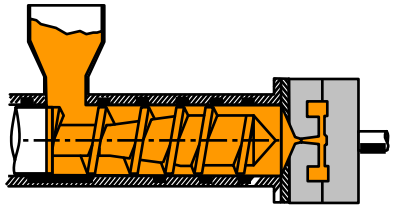
- **Weldline problem**
  - **Looks simple but has existed for years.**
  - **Original solution: CIM + Spray coating**

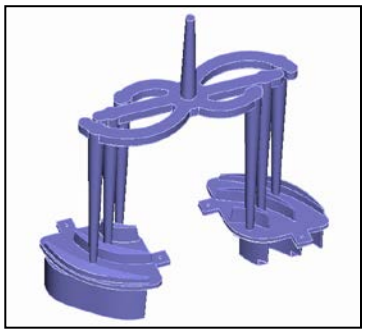


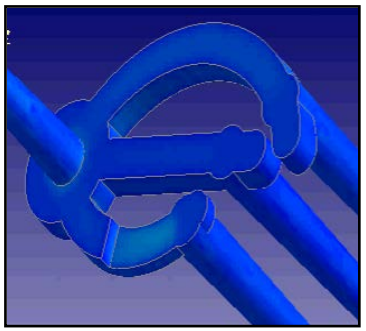
Source: Dragonjet Co., Taiwan

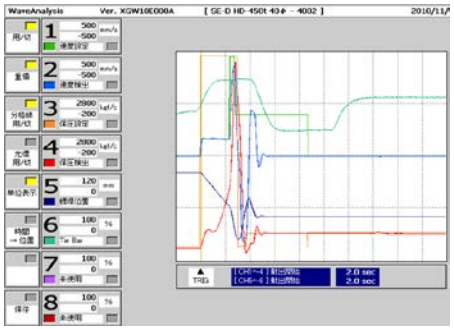
What People May Try?

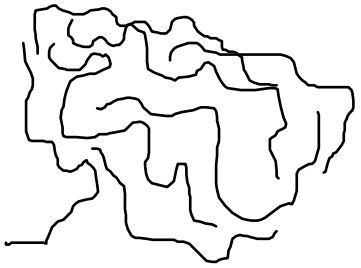
- Modify the process conditions
  - High injection speed , high mold temperature, …
- Revise mold design or part design
  - Runner layout? gate size?
- Change material?
  - Easy flow material?











Questions?

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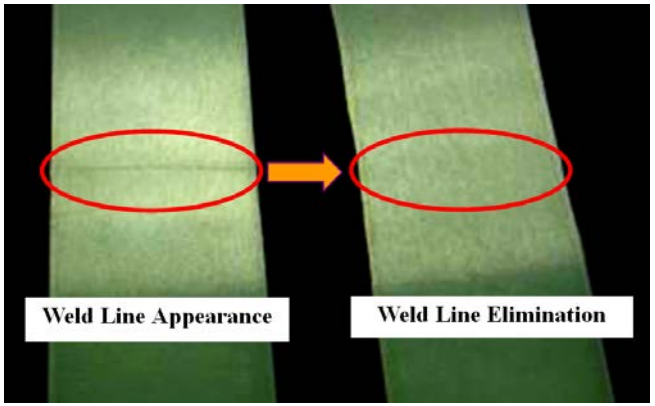
Dealing with a weldline problem,

> Someone may suggest to increase temperature to reduce the problem

- Increase melt temperature?
- Or using mold temperature control via different heating source to enhance mold temperature?
  - Heating through regular cooling channel
  - Heating via various variotherm methods



Variotherm: various mold heating and cooling methods.

Source: CYCU Prof. Shia-Chung Chen

Types for Vairotherm: Heating Methods

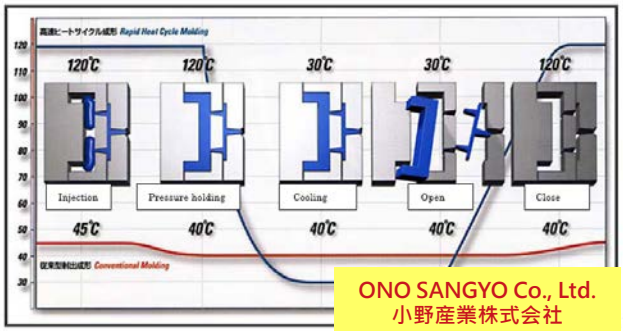


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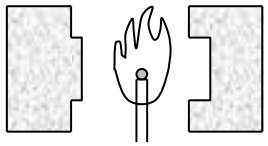
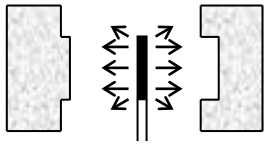
Fig 1. RHCM Process

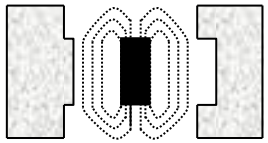
- Heating interior of moldbase
  - Steam heating (RHCM™)
  - High temperature coolant (Oil , water)
  - Electrical heater
  - …
- Heater outside moldbase or via mold surface
  - Flame heating (gas)

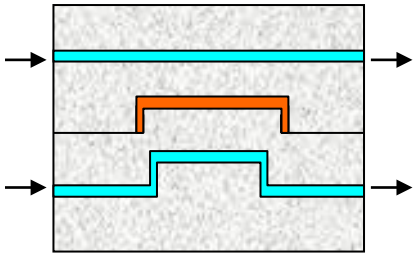


  - IR light lamp (infra-red light)



  - Induction Heating (Electricmagnetic)





- …

Rapid Heat Cycle Molding (RHCM™)

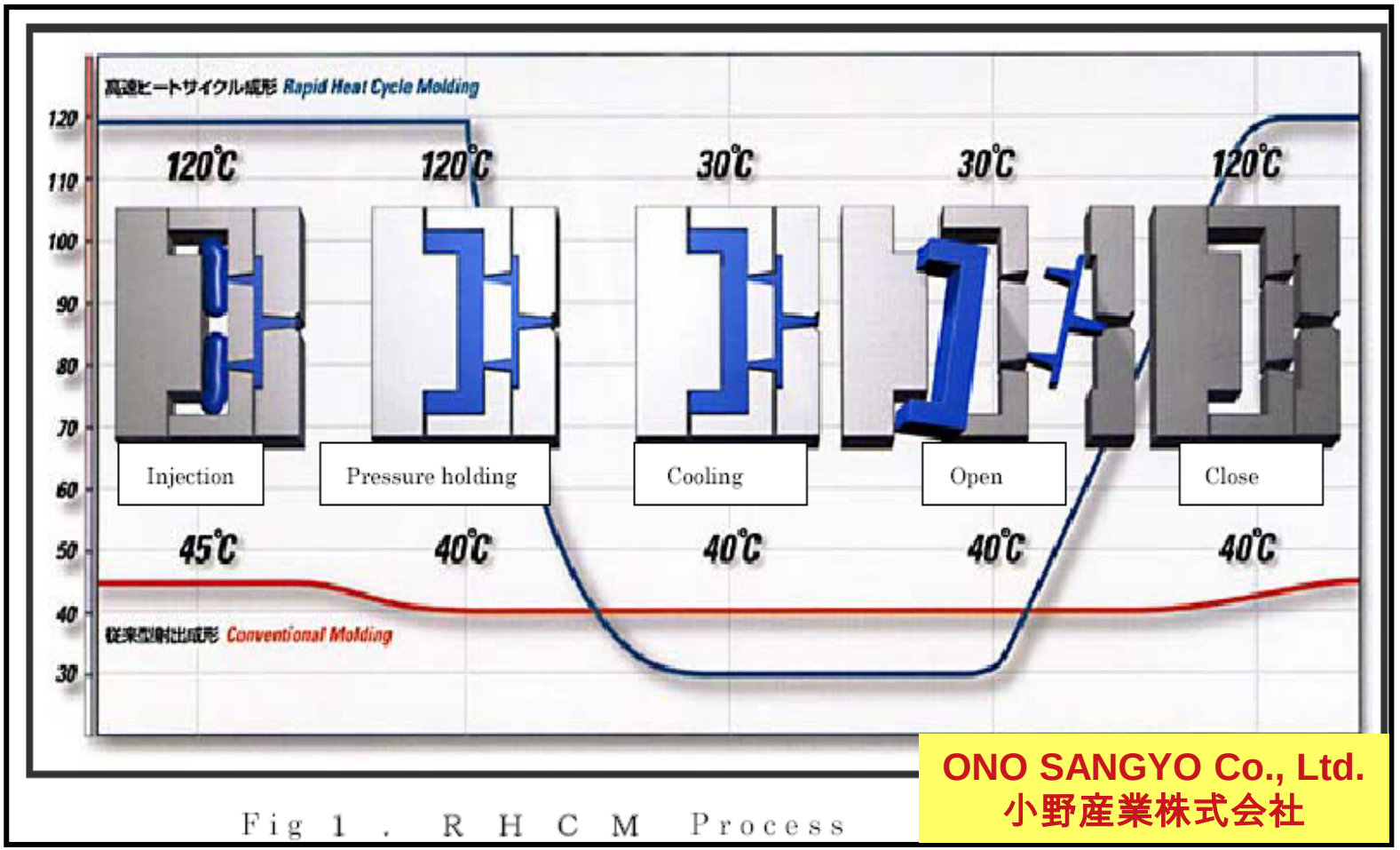


Fig 1. RHCM Process

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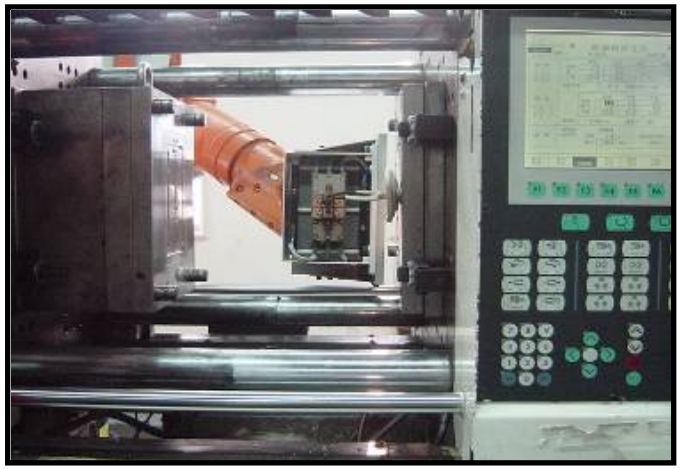
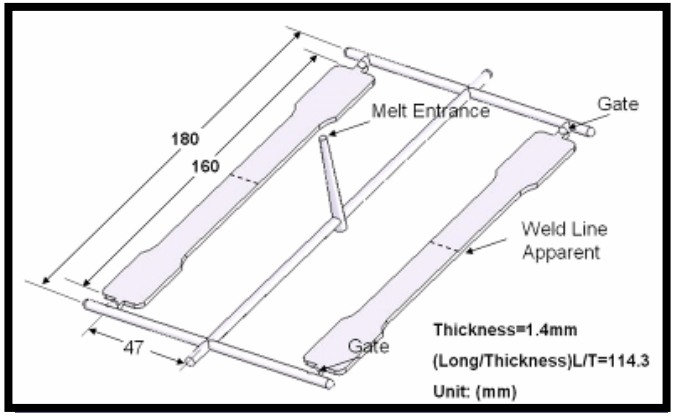
Induction Heating

Induction Heating With Robot



Tensile Bar Model



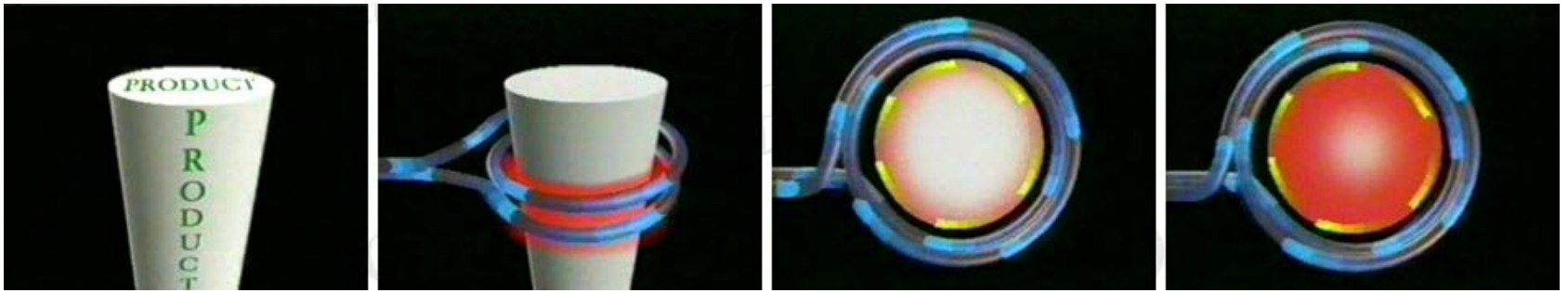
Material

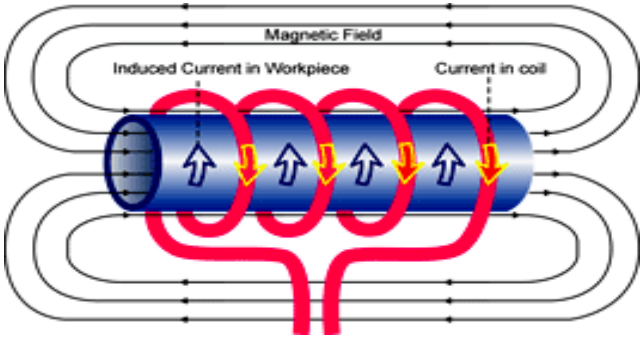
- ABS(PA-716) Tg : 105 ˚C
- Preheating Mold Temp: 50˚C
- Heating Time: 3~5.5 secs
- Induction heating Mold surface: 120˚C

Source: CYCU Prof. Shia-Chung Chen

Principle of Induction Heating

Principle: Electromagnetic field induces eddy current which generates heat within worked piece

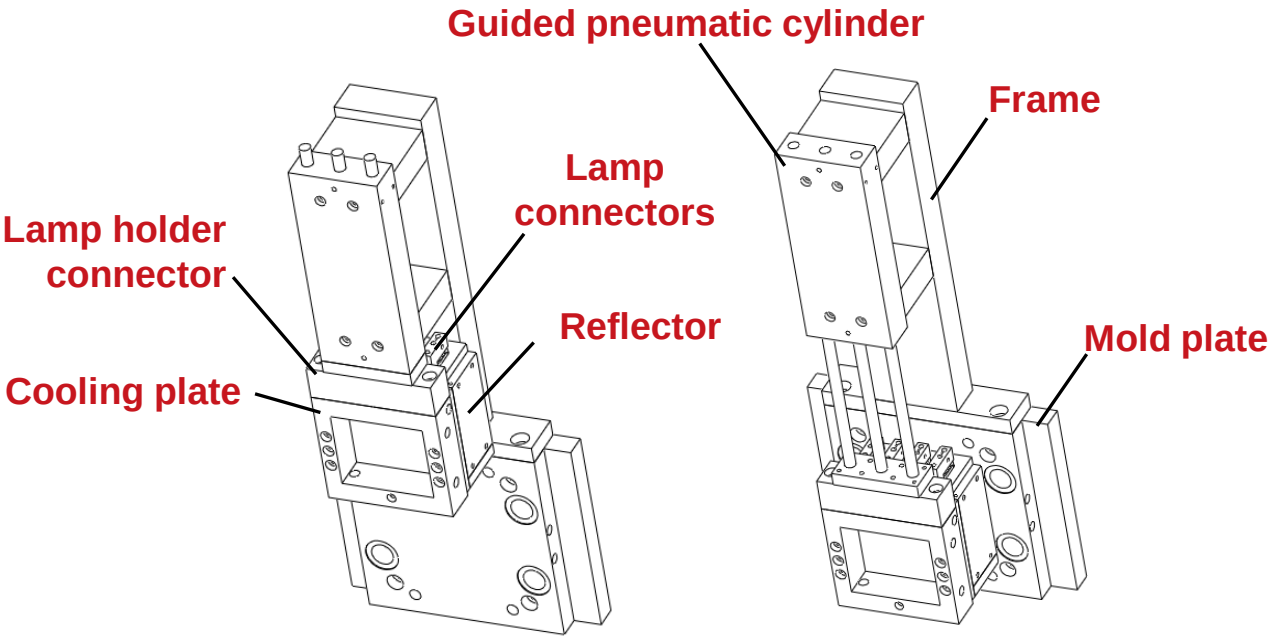




*Source：Ameritherm Inc.™

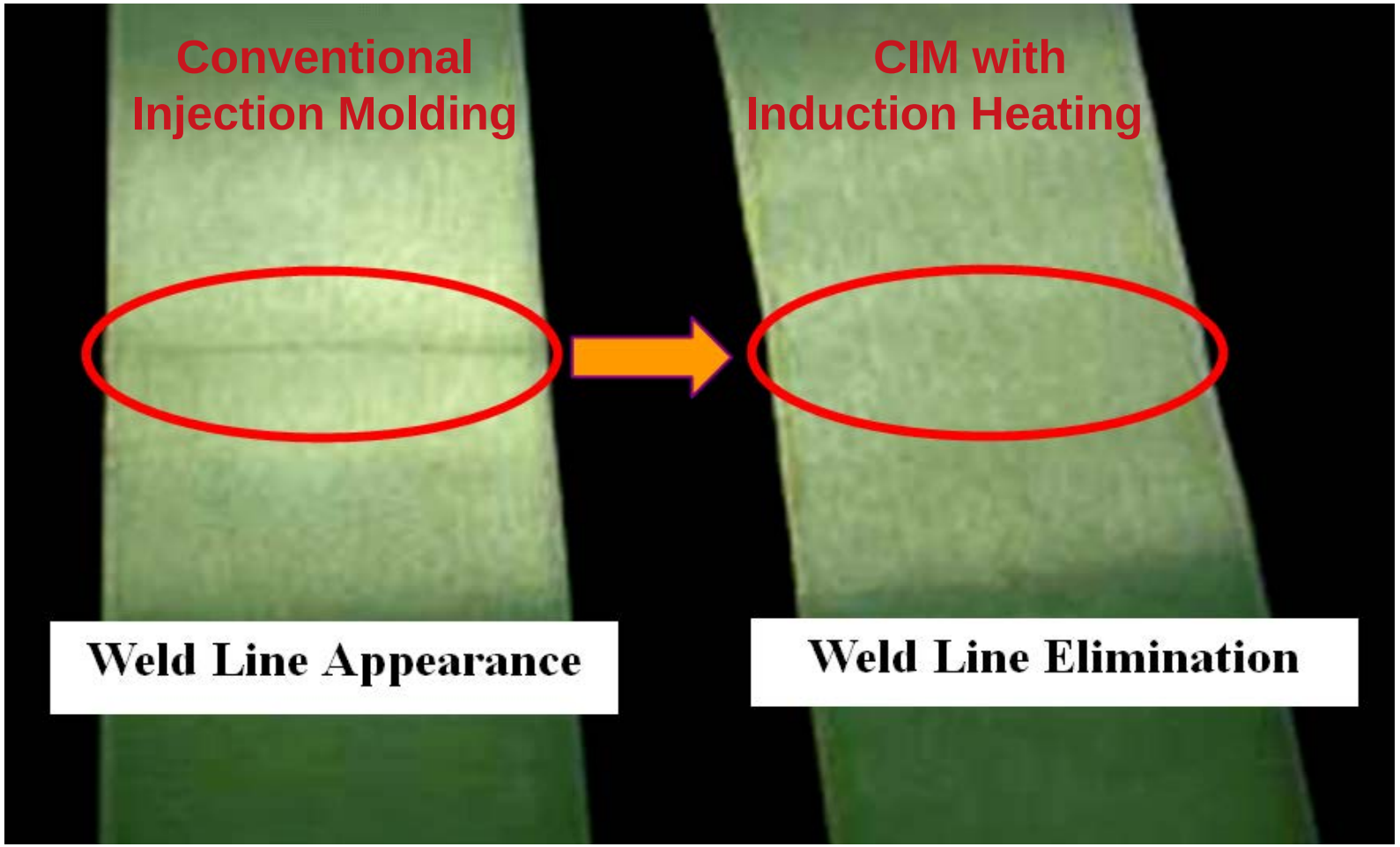
Infrared Heating System

> Schematic of the infrared heating system assembled on the standard mold base(180mm×180mm).



Source: Prof. Sheng-Jye Hwang, National Cheng Kung Univ.

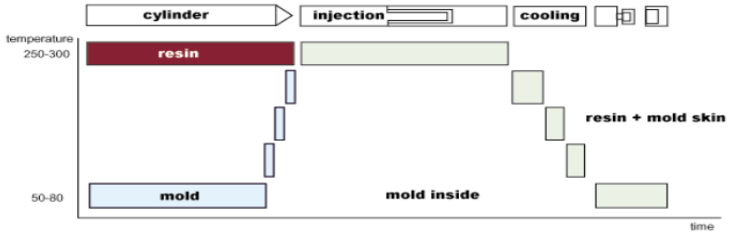
Eliminate the WeldLine Problem

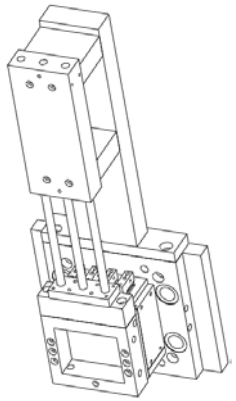


Source: CYCU Prof. Chen

Questions

- What really happened in interior heating method?
  - RHCM™ system?
  - E-mold™?
  - …
- What happened in mold-surface heating method?
  - IHM?
  - IR-heating?
  - …





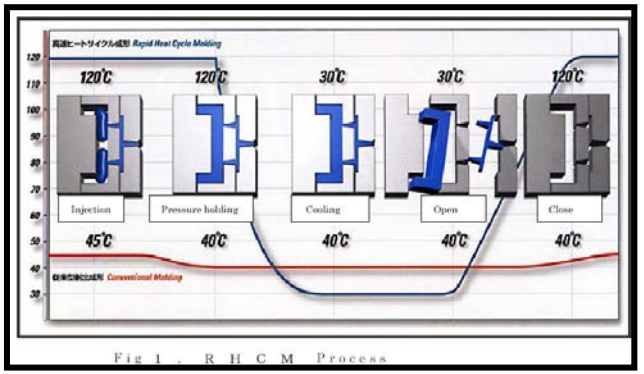
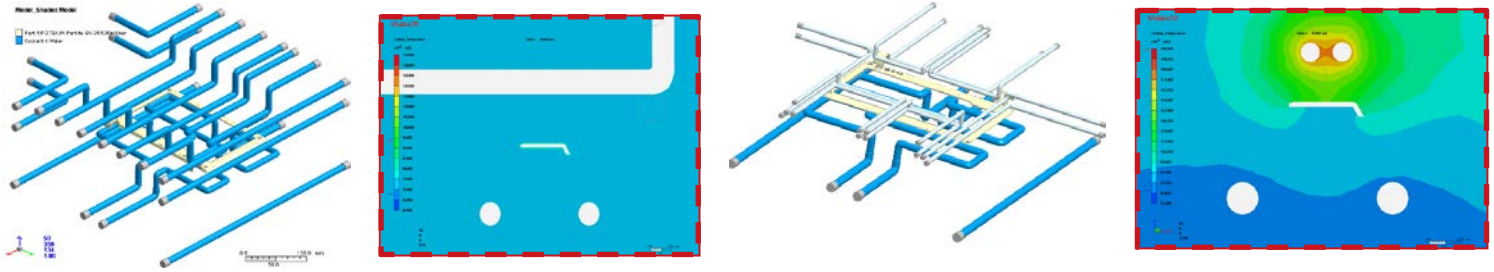


Fig 1. RHCM Process

Questions

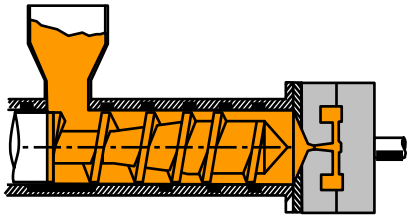
- No matter the heating source is from interior, or outside of the mold, or via some surface of mold
  - Why conventional cooling or heating can not solve this problem completely?
  - If we said, variotherm (such as RHCM, IHM,…) is better
    - The heating processes affect the mold system from time to time?
    - How the cooling mechanism is? It is not clear?
    - How to optimize the related parameters?



Investigation in Mold Temperature Control

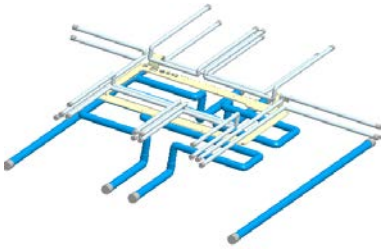
- Real experiments help realize this process, but
  - Inside of machine and mold, it is impossible to analyze all process information.
  - It is very difficult to measure all process parameter or properties, especially the dynamic properties.

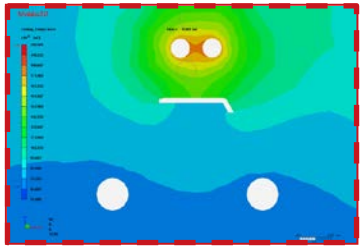
- CAE Technology
  - It can provide various inside information of process to enhance the new product or process development, or to help problem diagnosis and revision.
  - Even CAE, it is still very difficult.

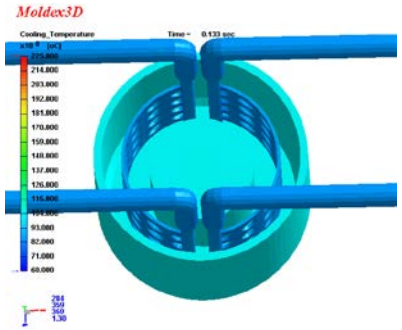


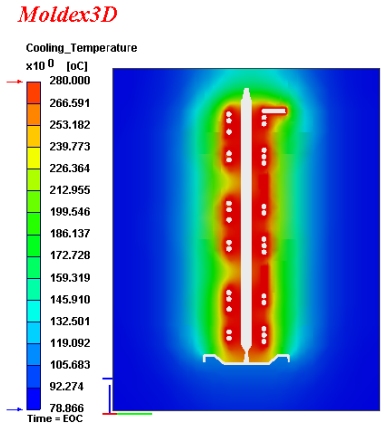
Why We Need Moldex3D

- We have developed True 3D Transient Cool Analysis Technology to cover
  - Conventional injection molding
  - Various mold control and management technologies
    - Variotherm technology
      - RHCM™, E-mold™, IHM, IR heating, and so on.
    - Conformal cooling
    - Hot runner
    - …, and so on









Previous Studies in Variotherm
Rome Was Not Built In One Day

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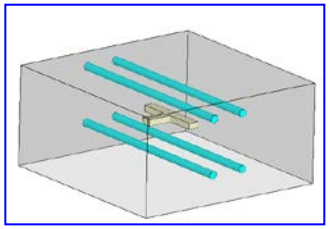
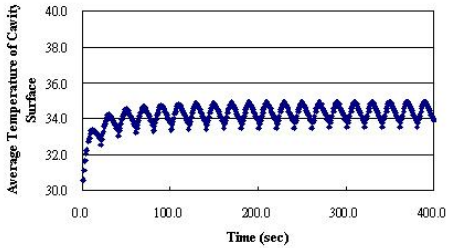
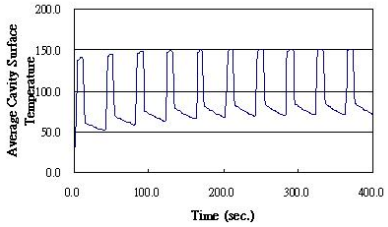
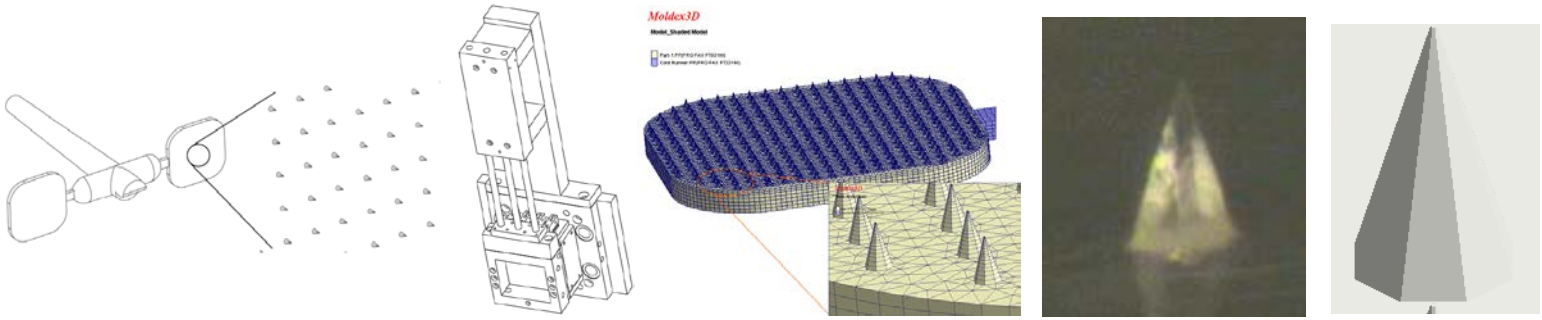
- Year 2006: 1st proposed CAE for RHCM™
  - YuFeng Chen et al, “True 3D and fully Transient Mold Temperature Simulation for RHCM process” , (ANTEC2006)







- Year 2006: for IR-heating
  - WenHsien Yang et al, “TRUE 3D NUMERICAL SIMULATION FOR MICRO INJECTION MOLDING”, (ANTEC2006)



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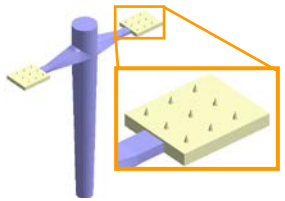
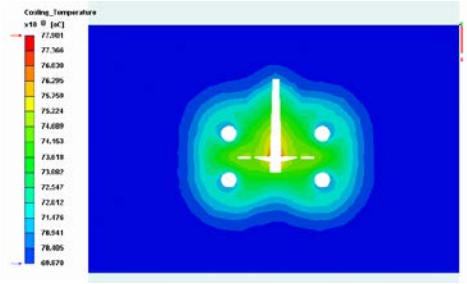
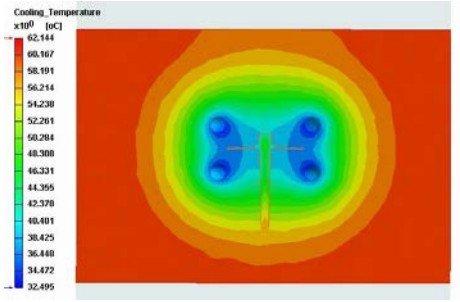
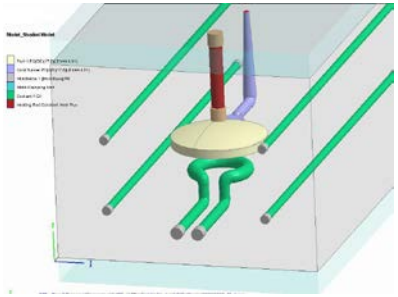
- Year 2007: for RHCM™
  - Yan-Chen Chiou, “Integrated true 3d simulation of rapid heat cycle molding process”, (ANTEC2007)

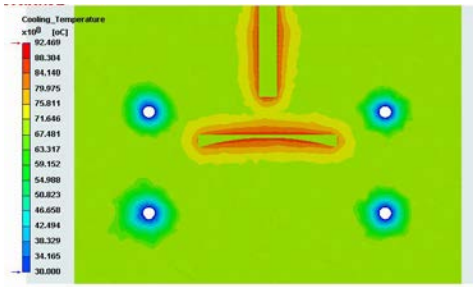


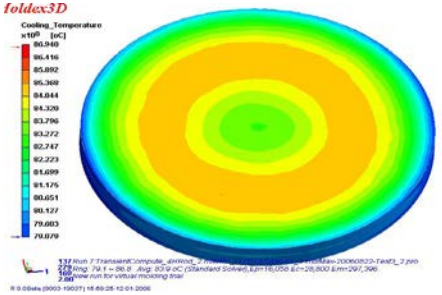




- Year 2007: for heater
  - Shia-Chung Chen et al, “An investigation on the temperature behavior in mold embedded with heater” , (ANTEC2007)







Previous Studies in Variotherm
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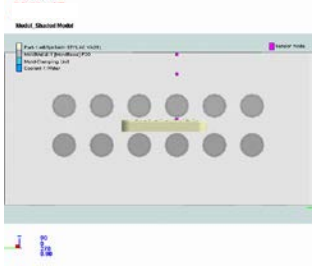
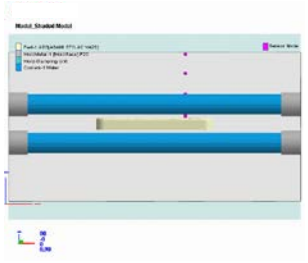
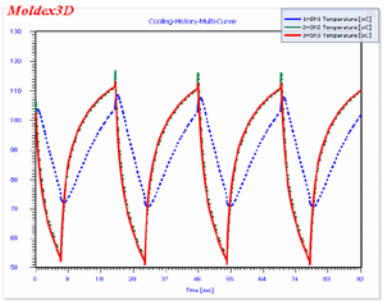
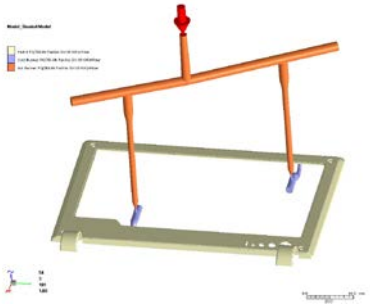
- Year 2009: for variotherm
  - Yan-Chen Chiou et al: “THERMAL FEATURE OF VARIOTHERM MOLD IN INJECTION MOLDING PROCESSES”,(ANTEC2009)

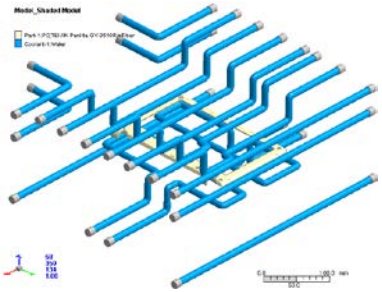


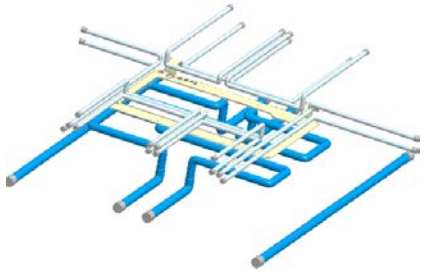




- Year 2010: for variotherm
  - I-Sheng Hsieh et al, “Investigation on Various Variotherm Processes in Injection”, (ANTEC2010)







Previous Studies in Variotherm
Rome Was Not Built In One Day

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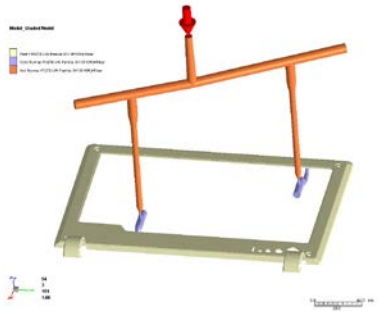
- Year 2011: Overview's paper
  - C-T Huang et al, "The Effects of Various Variotherm Processes and Their Mechanisms on Injection Molding", Intern. Polymer Processing, No.3, 265-274 (2011)

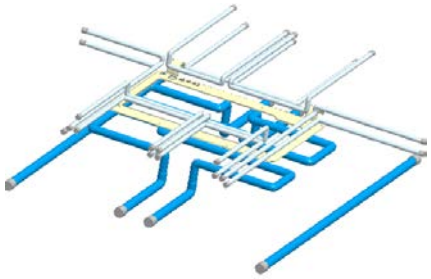
SPECIAL ISSUE ON INJECTION MOLDING ANSD MOLDS

C.-T. Huang [1], I.-S. Hsien [1], C.-H. Tsai [1], Y.-C. Chiou [1], C.-C. Tang [2]*

[1] CoreTech System Co., Ltd., Hsinchu County, Taiwan, R.O.C.
[2] Dragonjet Co., Ltd., Taipei, Taiwan, R.O.C.

The Effects of Various Variotherm Processes and Their Mechanisms on Injection Molding





True 3D Transient Cool Analysis

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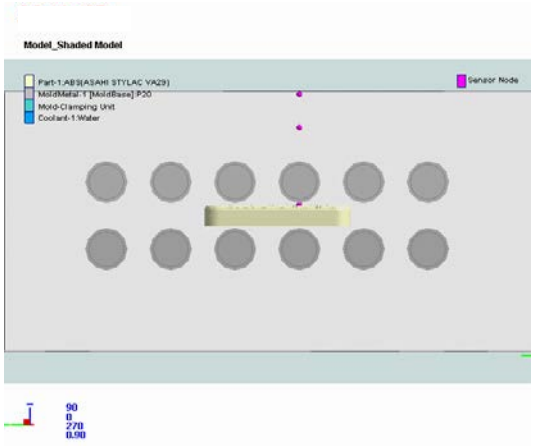
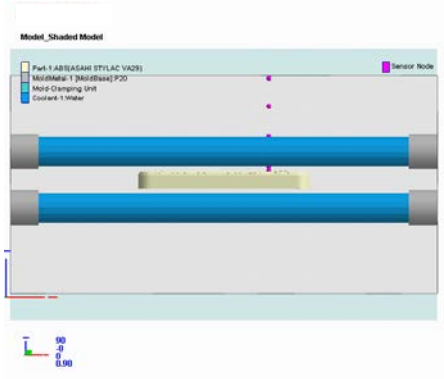
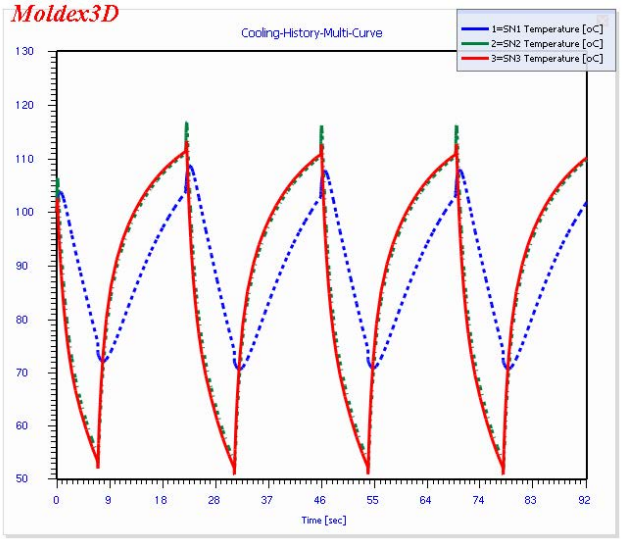
- What is True 3D Transient Cool Analysis
  - It is used to predict and analyze what the dynamic thermal feature inside the injection mold system at various moments in time.
  - It is useful for CIM or various mold control system such as RHCM, IHM, and so on







Theory

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True 3D theory

> Mass Conservation

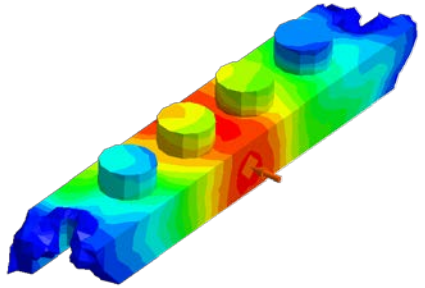
$$\frac{\partial \rho}{\partial t} + \nabla \cdot (\rho \mathbf{v}) = 0$$

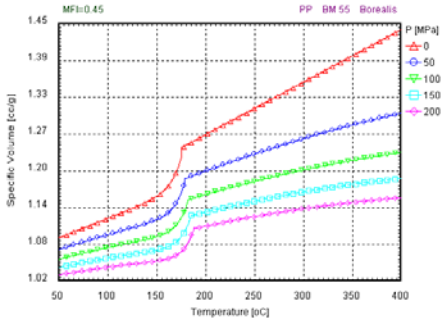
> Momentum Conservation

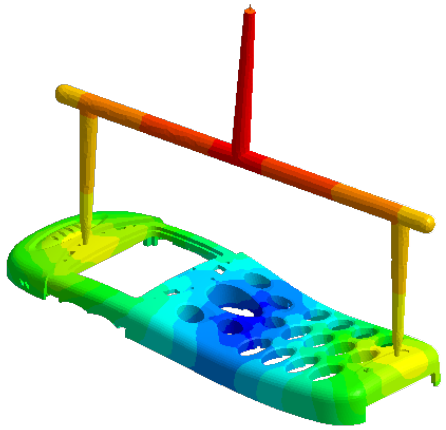
$$\rho \frac{D\mathbf{v}}{Dt} = -\nabla \cdot \mathbf{T} + \rho \mathbf{g}$$

> Energy Conservation

$$\rho C_P \left(\frac{\partial T}{\partial t} + \mathbf{u} \cdot \nabla T \right) = \nabla (\mathbf{k} \nabla T) + \eta \dot{\gamma}^2$$







Numerical Approaches

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> Numerical approaches:
  - Cycle-averaged approach
  - Fully transient true 3D approach

> Energy conservation equation:

$$\rho C_p \frac{\partial T}{\partial t} = k\left(\frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2} + \frac{\partial^2 T}{\partial z^2}\right) + q(t)$$

T ： Temperature

ρ： Density

Cp： Thermal capacity

k ： Thermal conductivity

$q(t)$： Heater/heat resources

Cycle-averaged Approach

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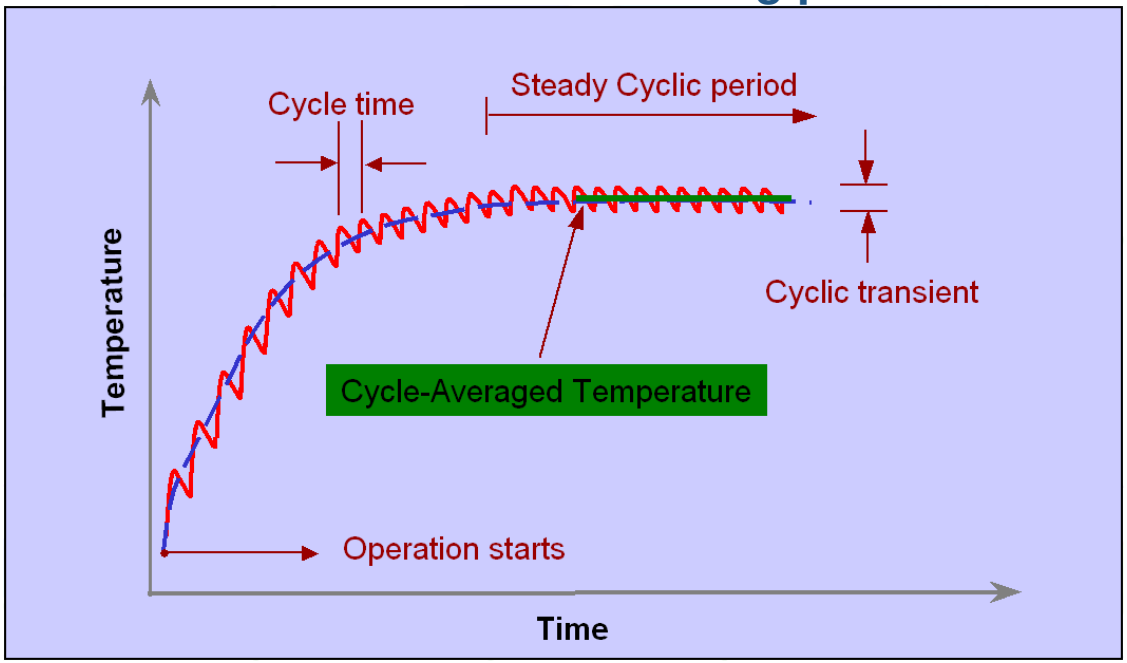
> Cycle-averaged approach

$$k_m \nabla \overline{T} = 0$$ **(MoldBase)**

– is not suitable for variotherm molding process.

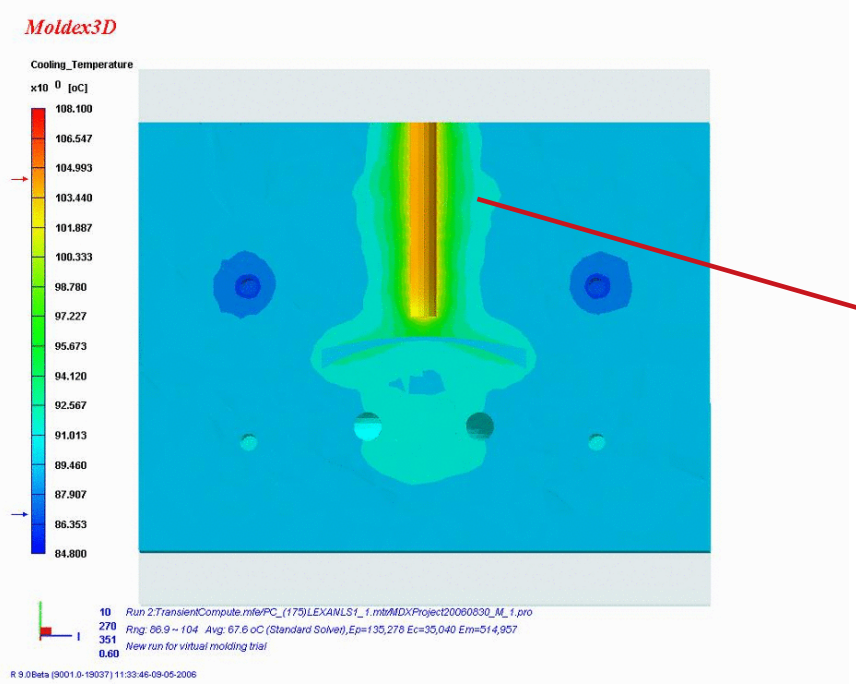


Fully Transient True 3D Approach

- Integrated fully transient true 3D approach

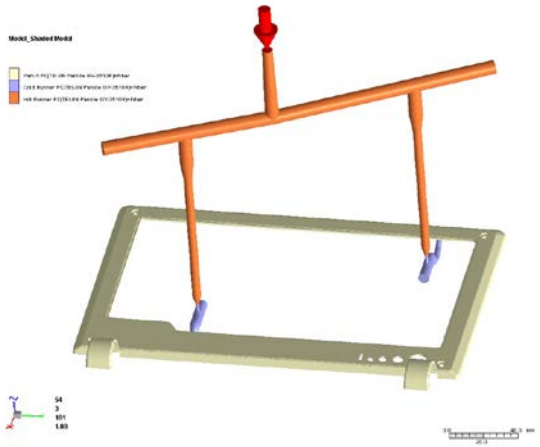
$$k_m \nabla^2 T = \rho C_p \frac{\partial T}{\partial t}$$ **(MoldBase)**

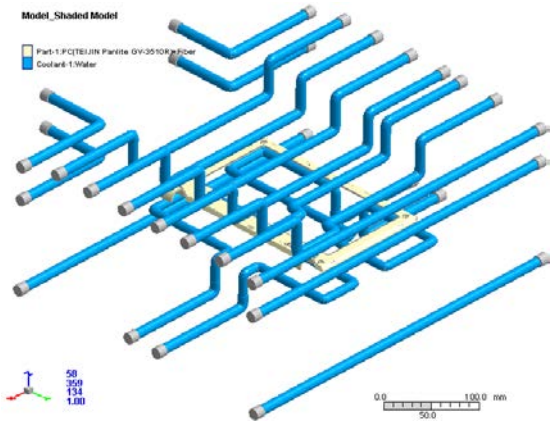
  - is able to simulate the temperature change in RHCM.

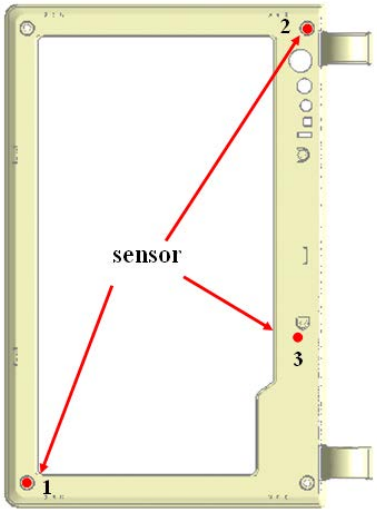


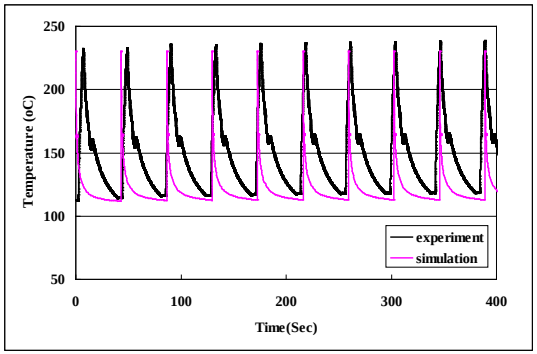
Heating rod

Validation for Transient Features







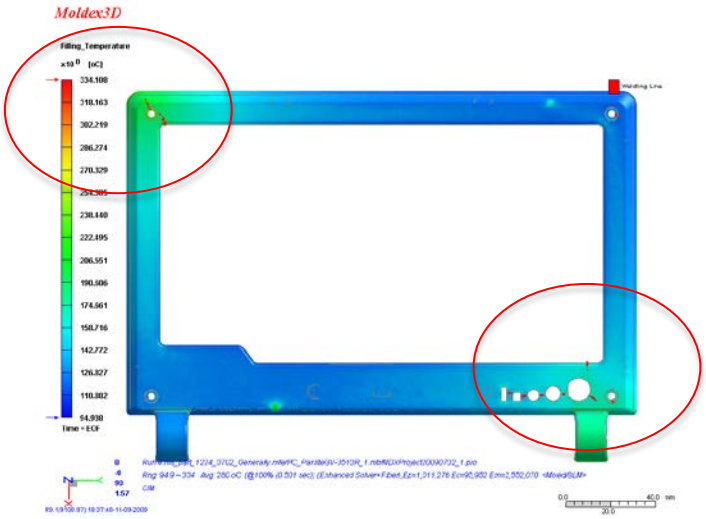


Reference: Intern. Polymer Processing, No.3, 265-274 (2011)

Problems from Customer

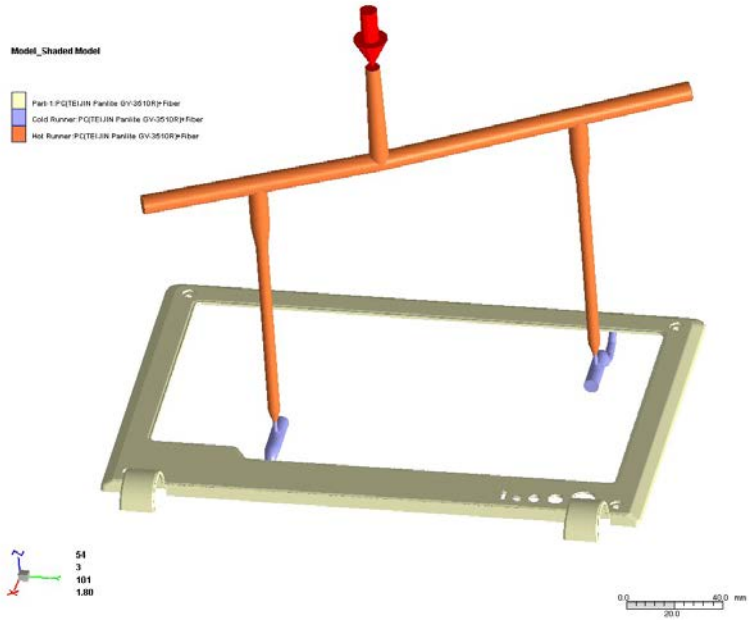
- Major problems
  - Weldline:
    - Few room to tune up
    - Using spray coating with high cost

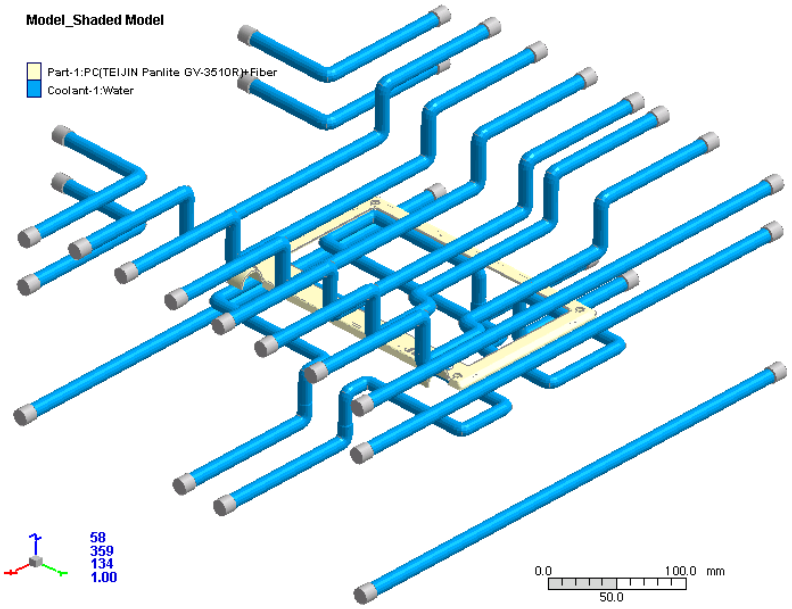
- Benefit of Moldex3D
  - Weldline:
    - Help design validation via RHCM and IHM
    - Cost down 1/3



Source: Dragonjet Co., Taiwan

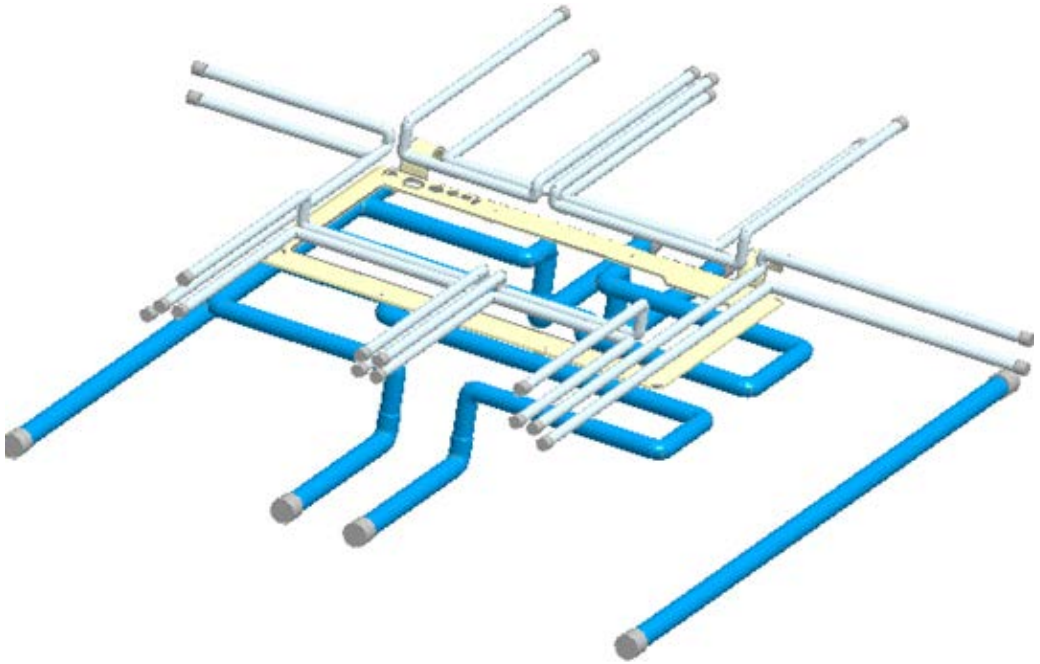
Runner and Cooling Channel Layout: CIM System

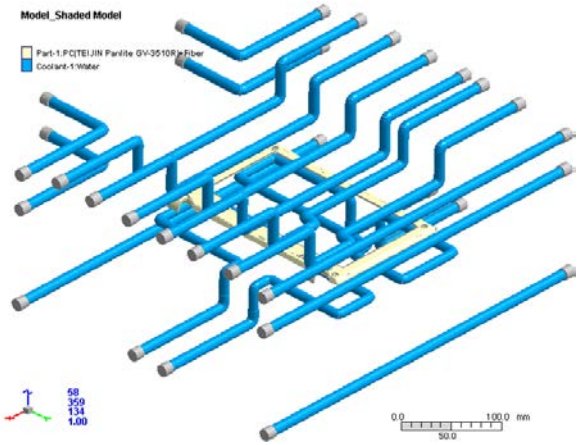




The cooling channel layout

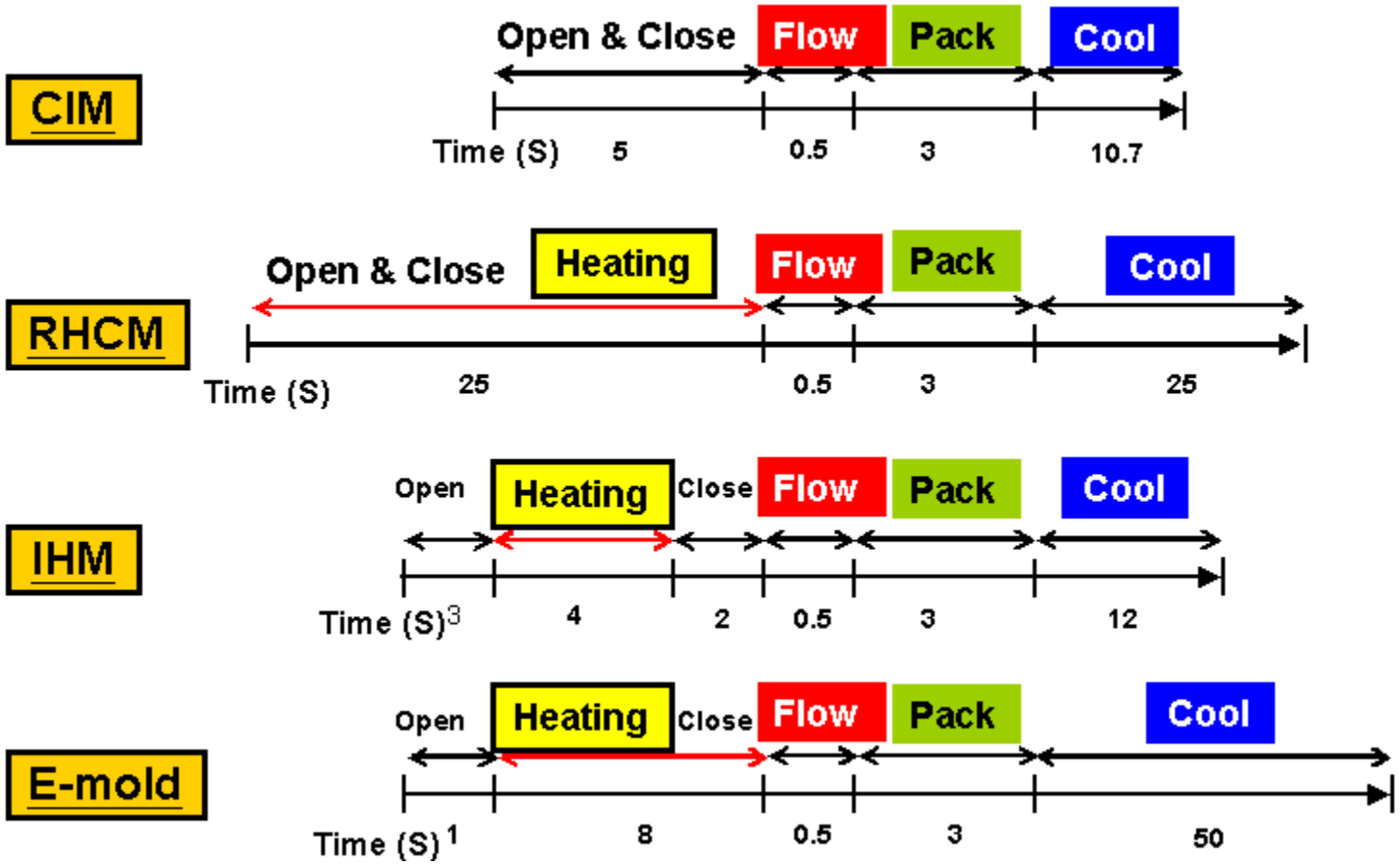
The coolant channel of RHCM





The coolant channel layout of RHCM

Time Sequence of Each Cycle



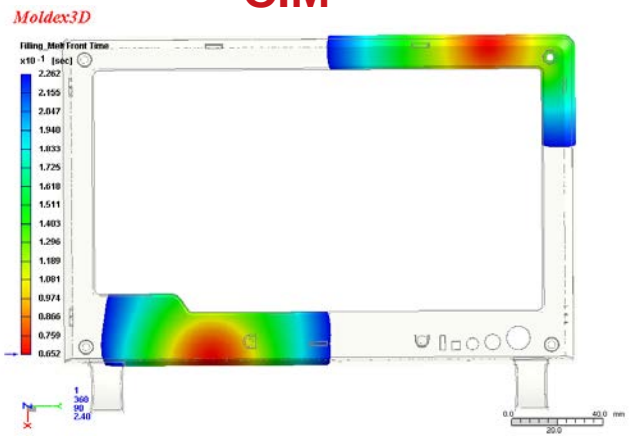
Melt Front Behavior

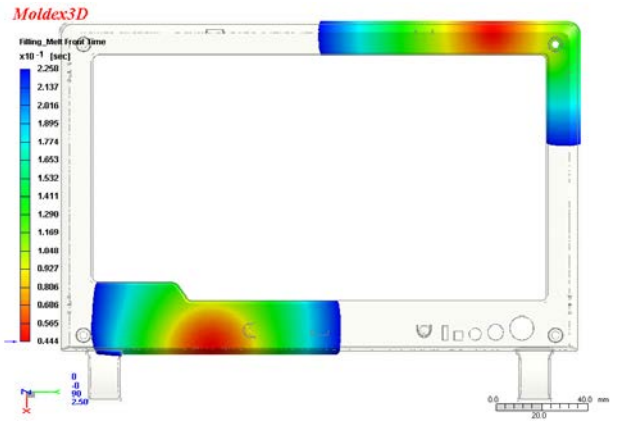
Moldex3D

CIM

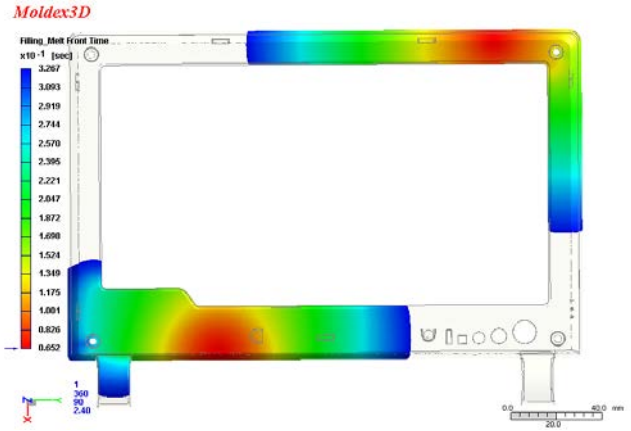
RHCM™

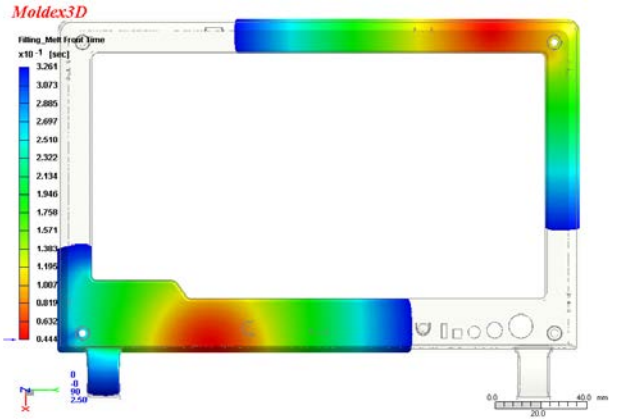
45%





65%





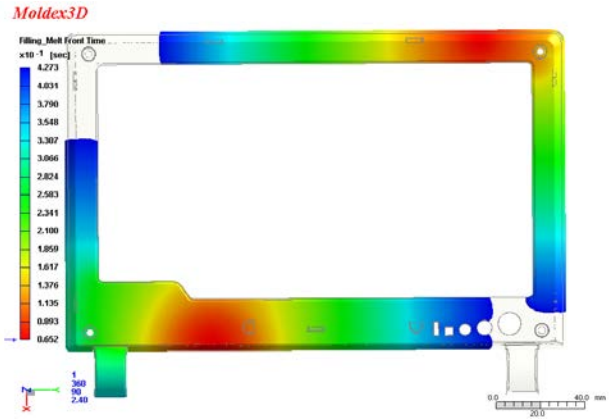
Melt Front Behavior

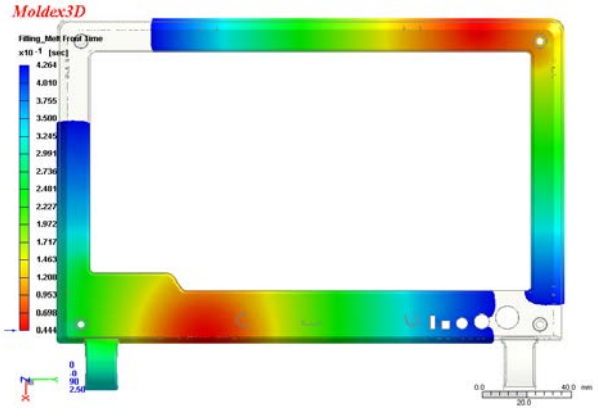
Moldex3D

CIM

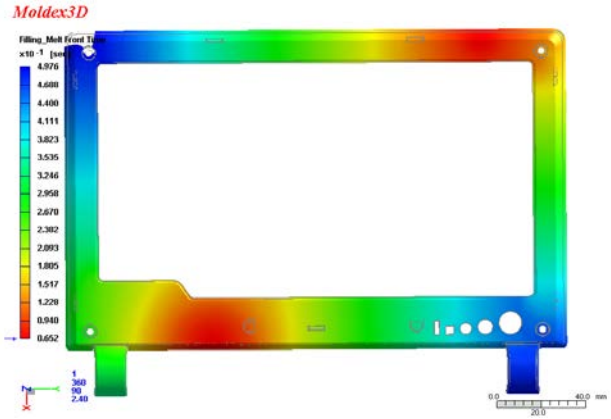
RHCM™

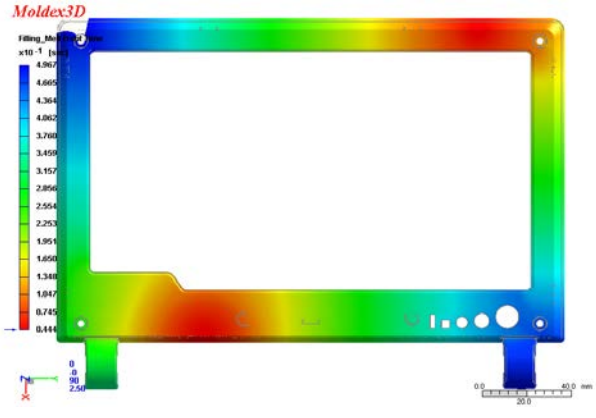
85 %



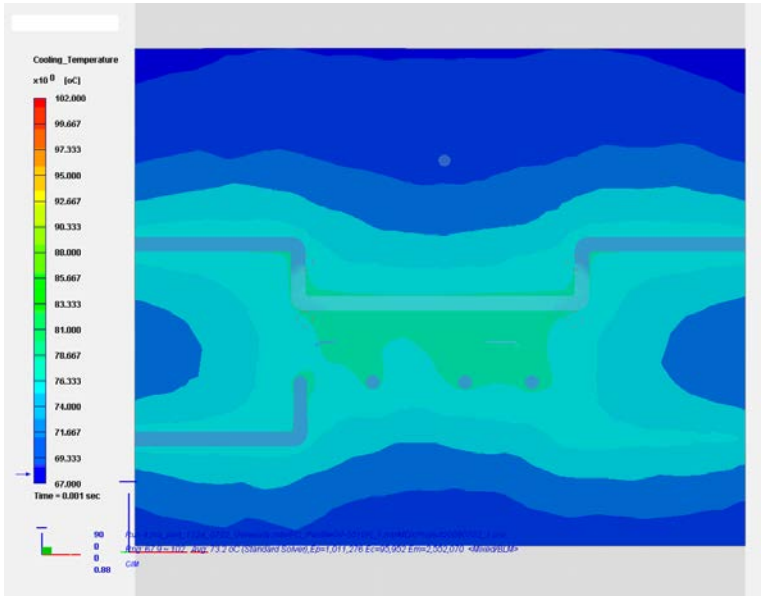


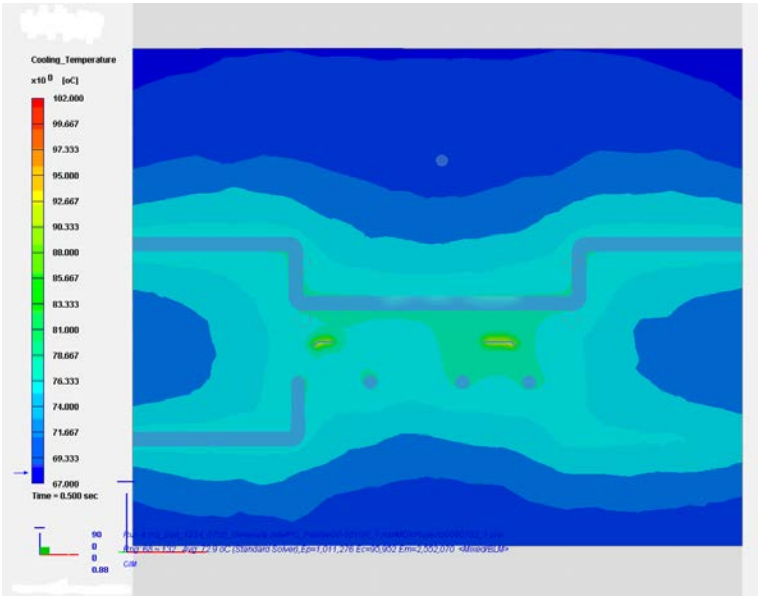
99 %



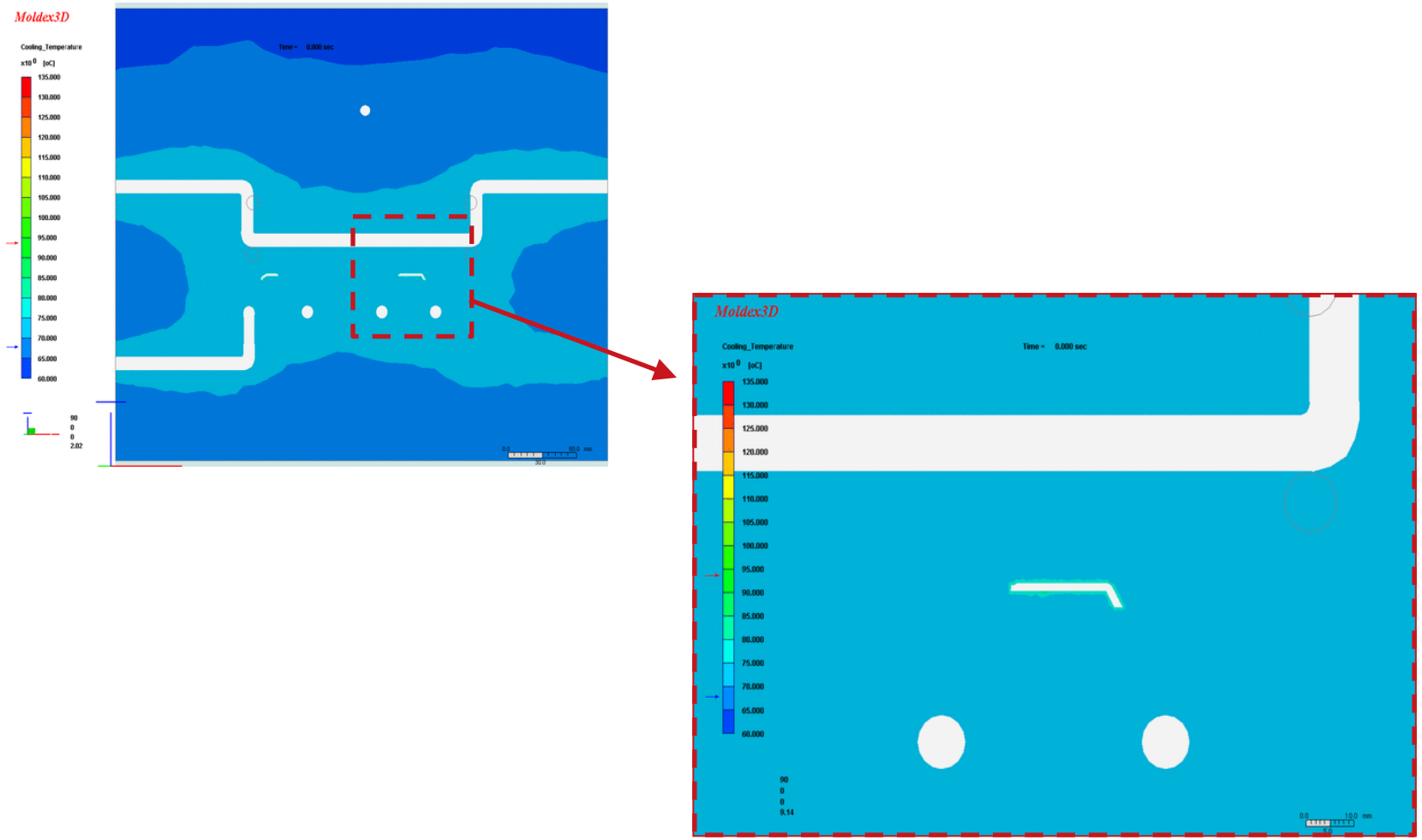


The temperature distribution of moldbase during filling phase in CIM

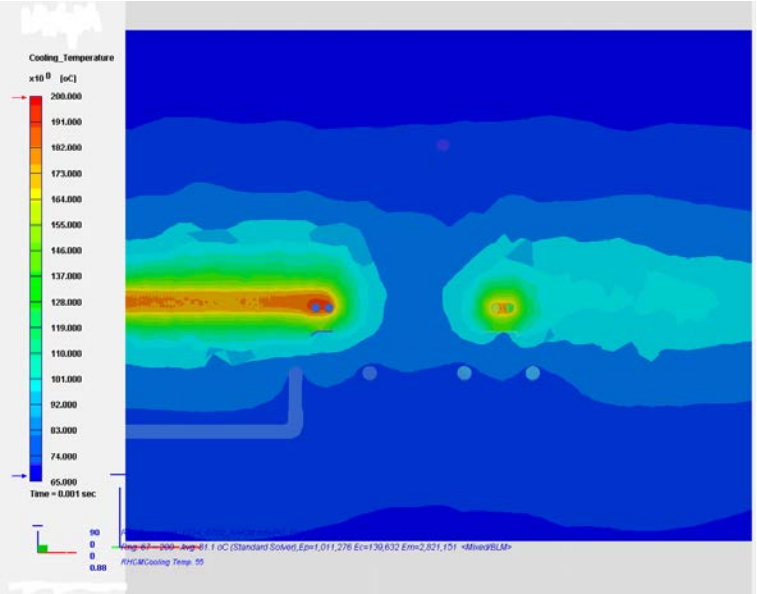




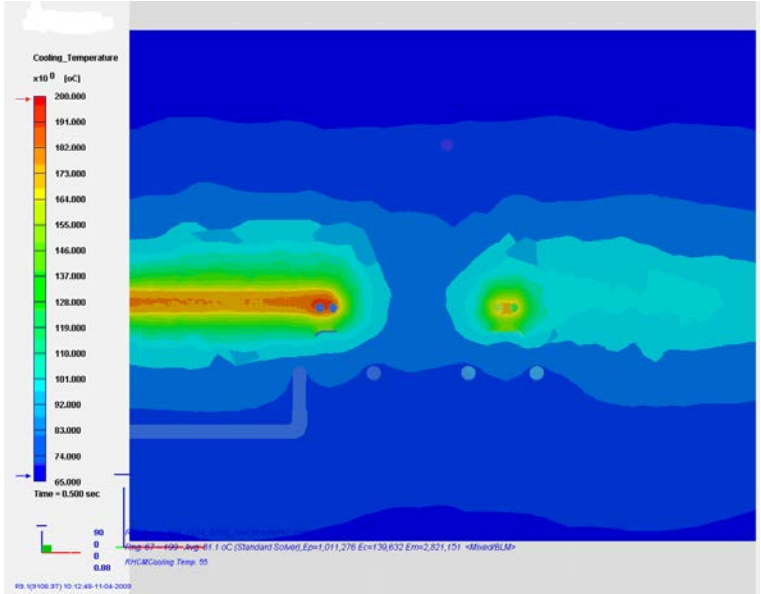
Cross-sectional Mold temperature variation of CIM



The temperature distribution of moldbase during filling phase in RHCM (heating cavity side)

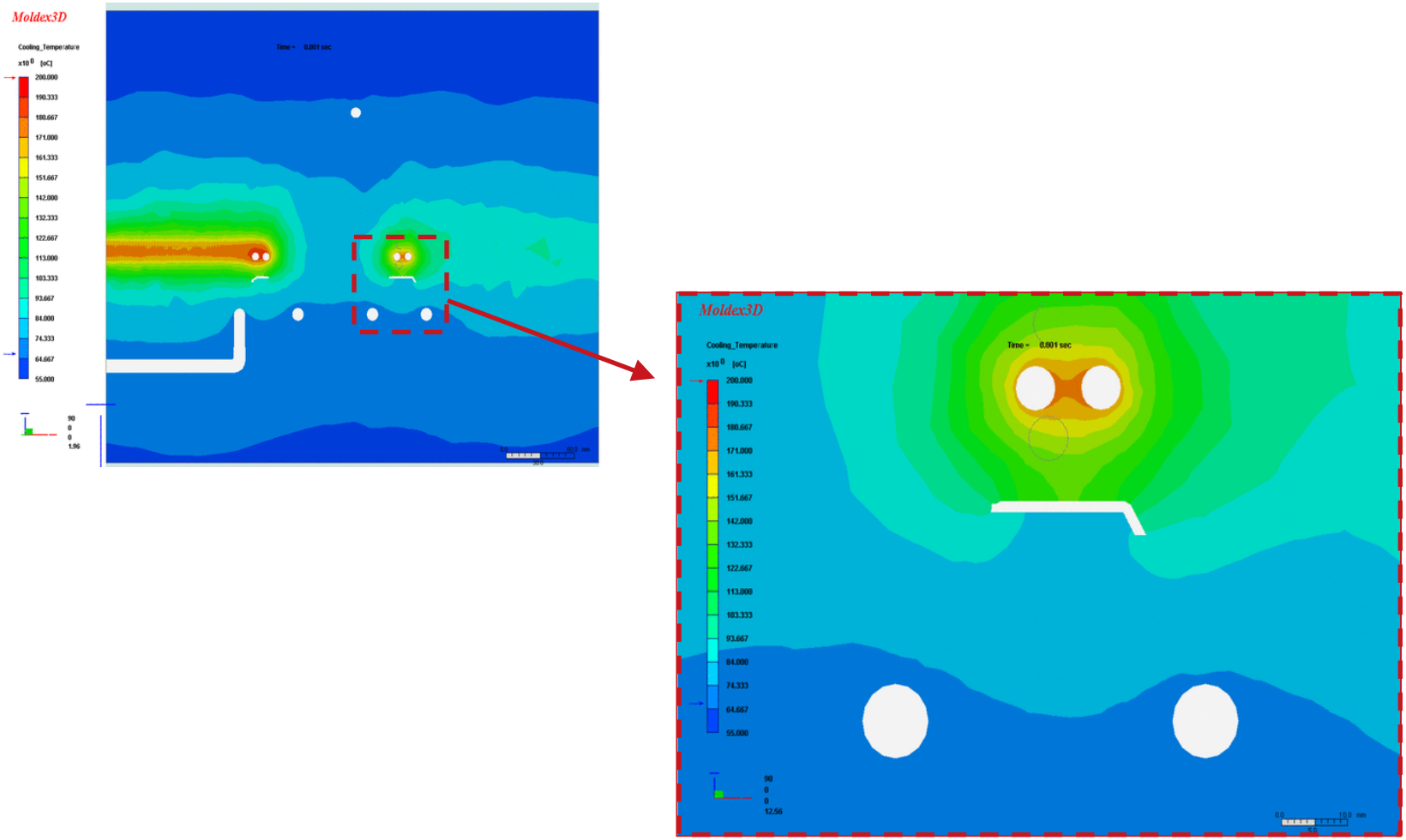


0.001s

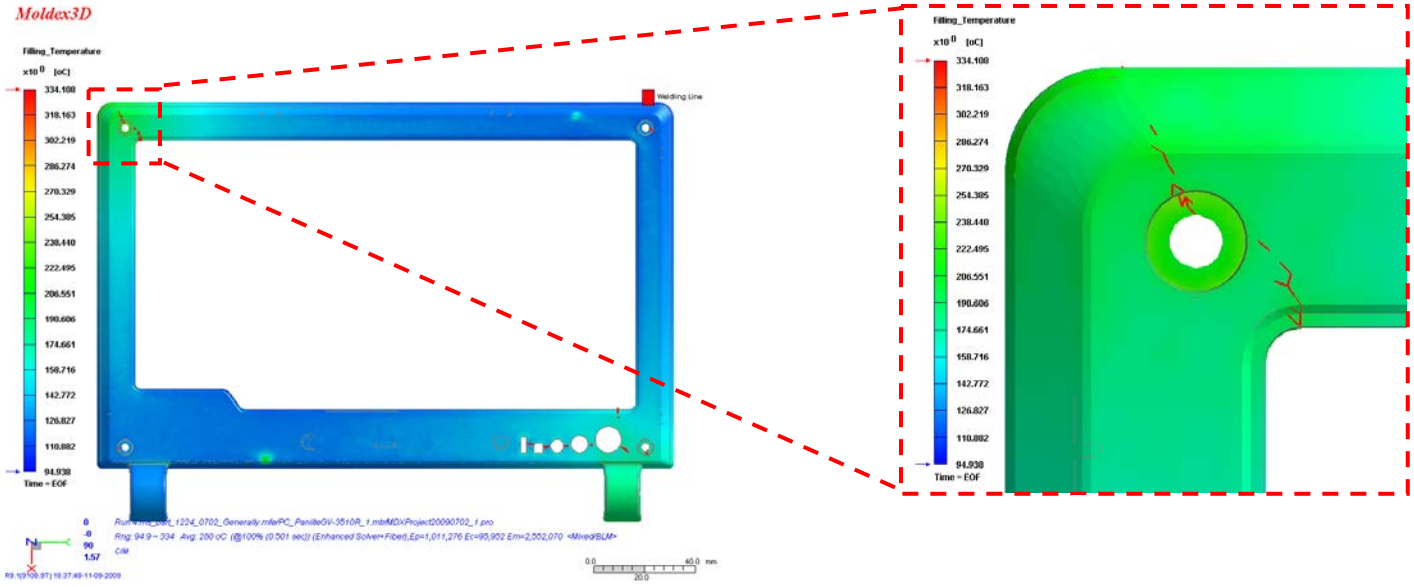


0.5s (end of filling)

Cross-sectional Mold temperature variation of RHCM (heating cavity side)



Weldline temperature

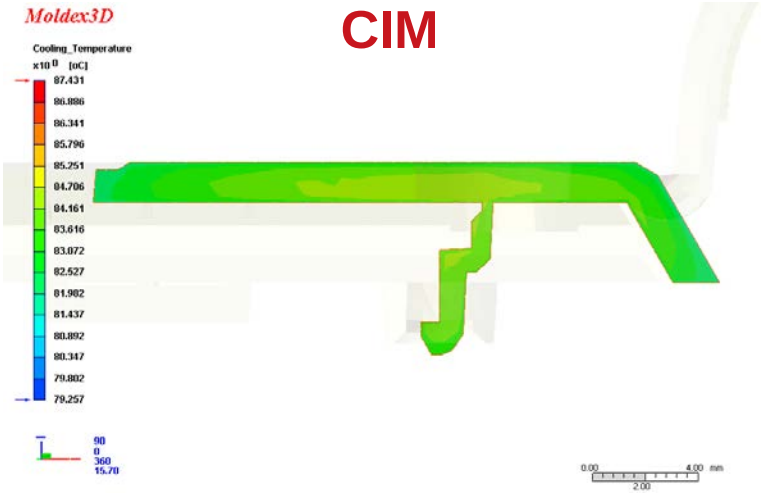


	Weldline temperature
CIM	170°C ~200°C
RHCM	190°C ~220°C
IHM	205°C ~235°C
E-mold	210°C ~240°C

The temperature distribution inside the mold at the end of cooling

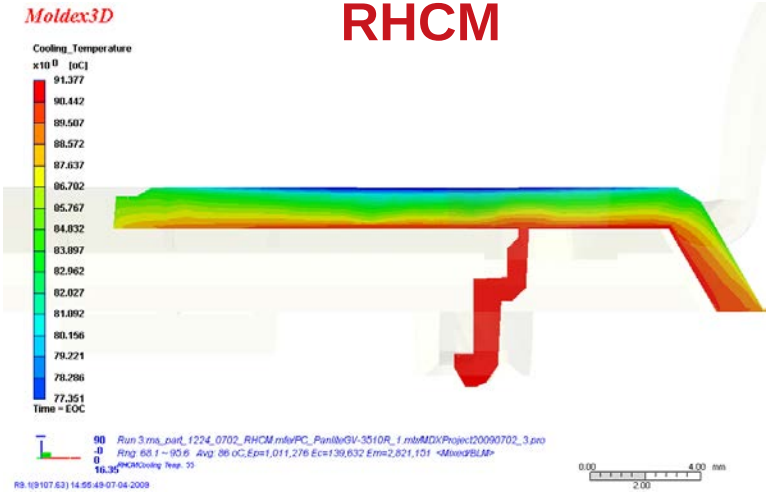
Moldex3D

CIM



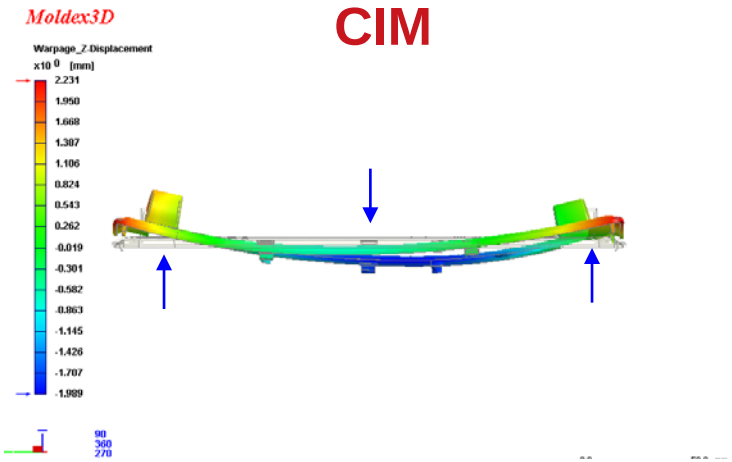
Temperature: 79~86°C at 10.7 sec

RHCM



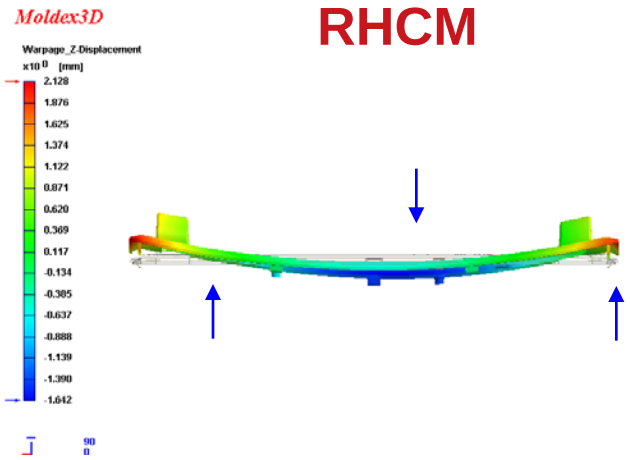
Temperature: 77.4~91.4°C at 25sec

Z displacement result



CIM

Displacement: -1,98~2.2mm



RHCM

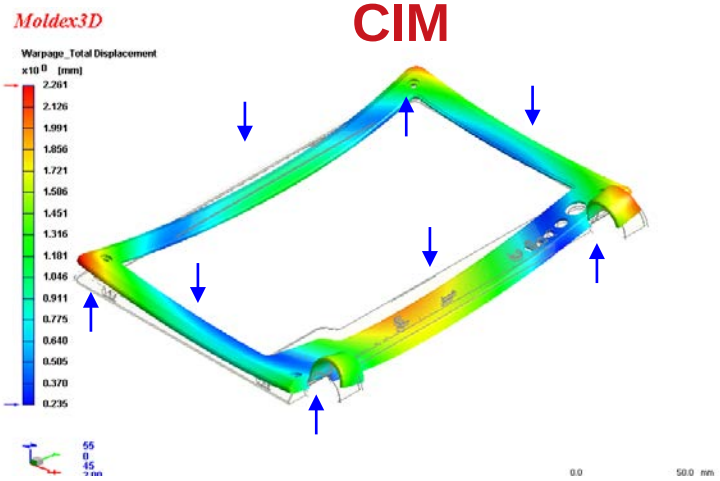
Displacement: -1.6~2.13mm

Improvement: 11%

Total displacement result

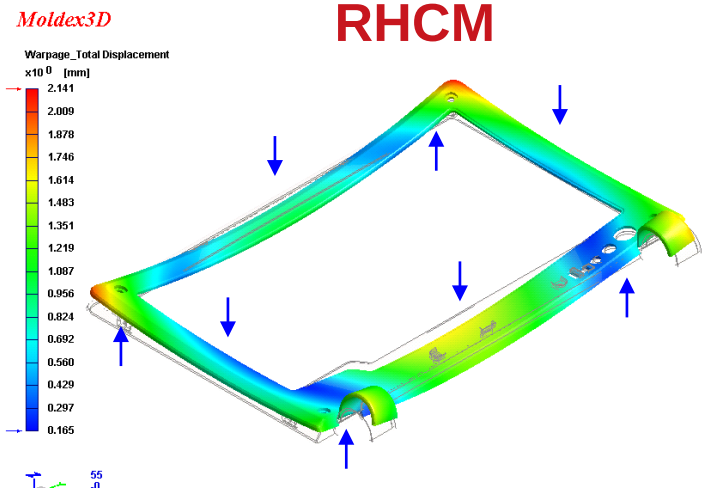
Moldex3D

CIM



Displacement: 0.23~2.2mm

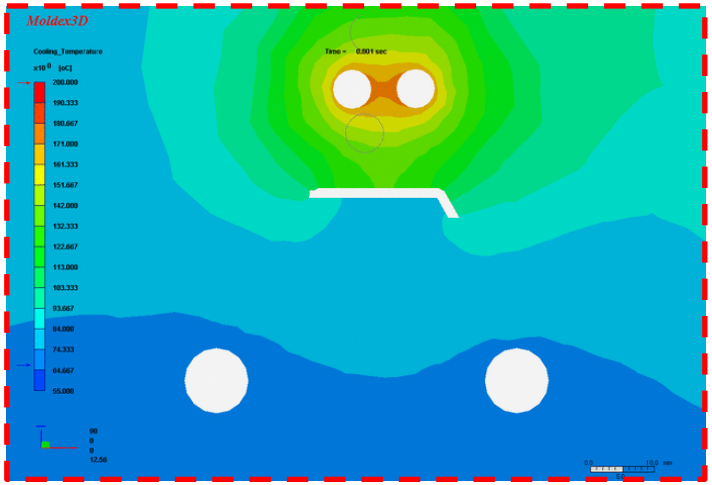
RHCM

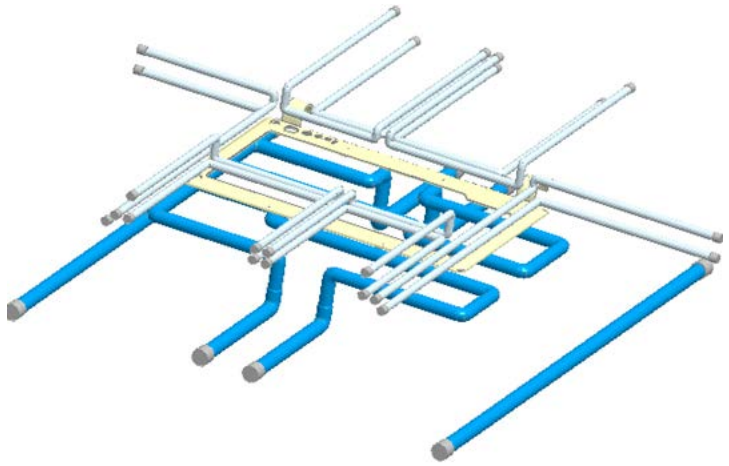


Displacement: 0.16~2.14mm

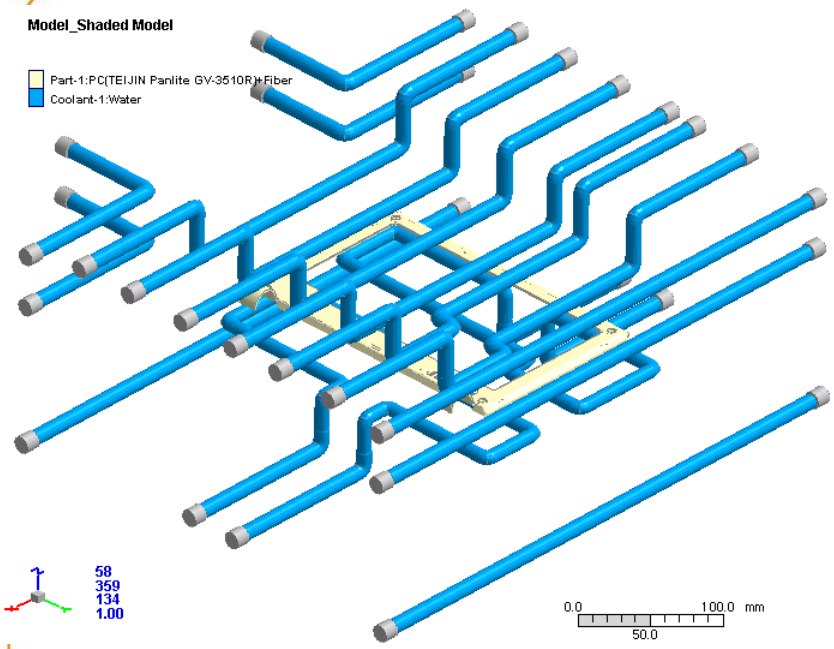
After Moldex3D Analysis

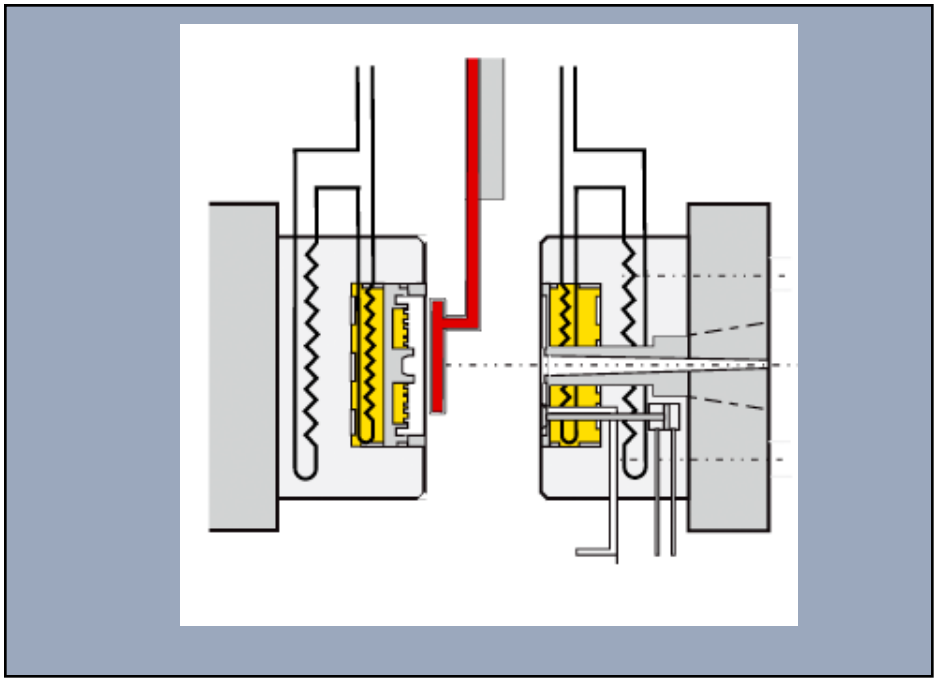
- RHCM
  - Can reduce weldline problem
  - But cost > (CIM + spray coating)



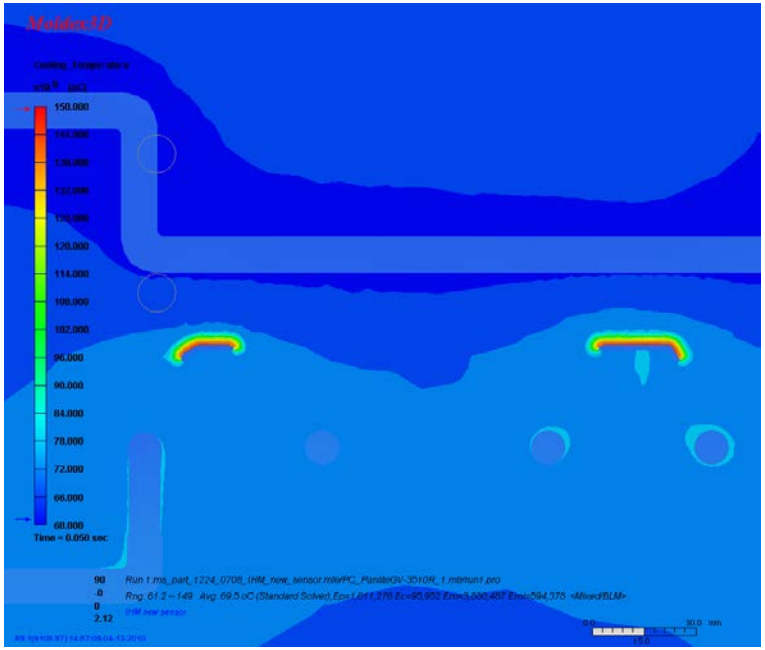


Advanced Study in IHM





The temperature distribution of moldbase during filling phase in IHM (heating to 150°C)



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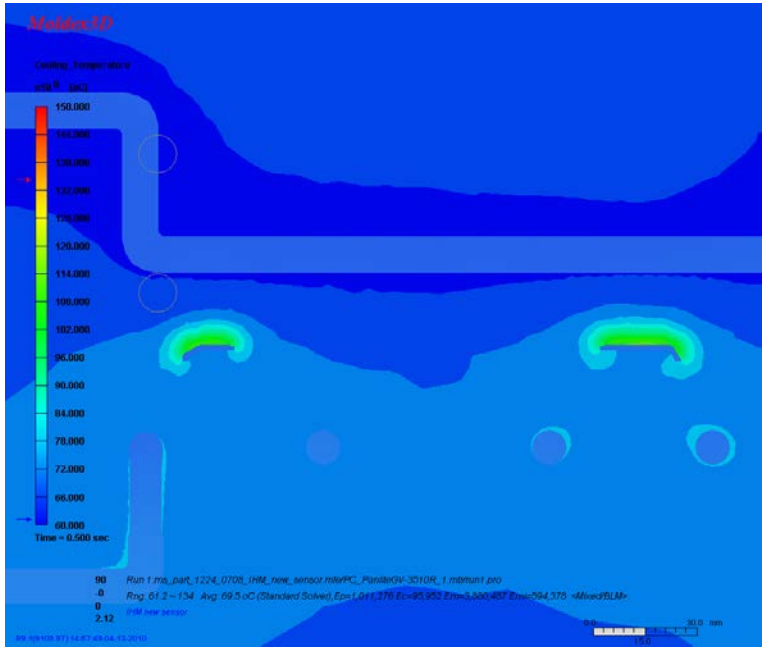
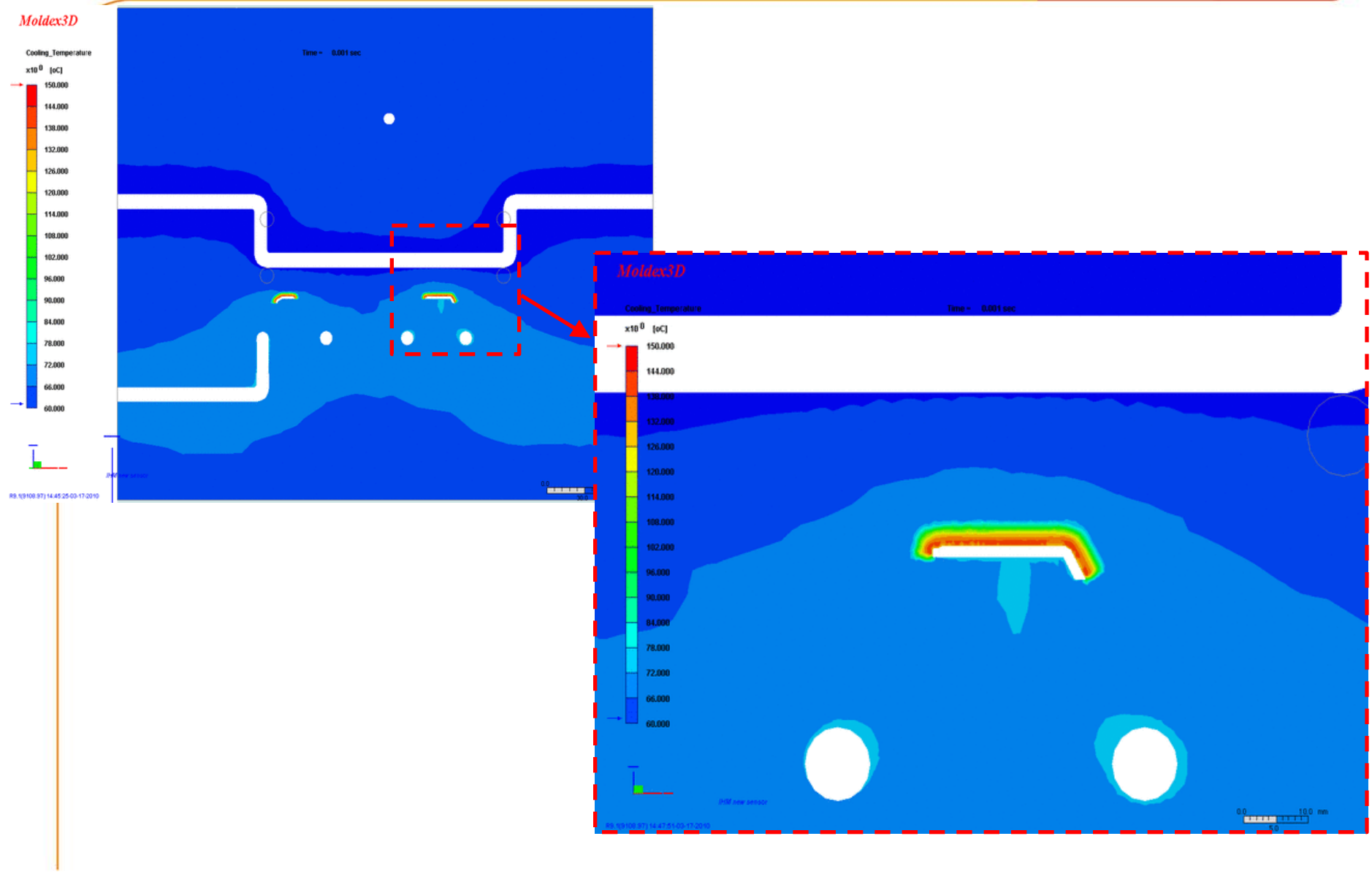
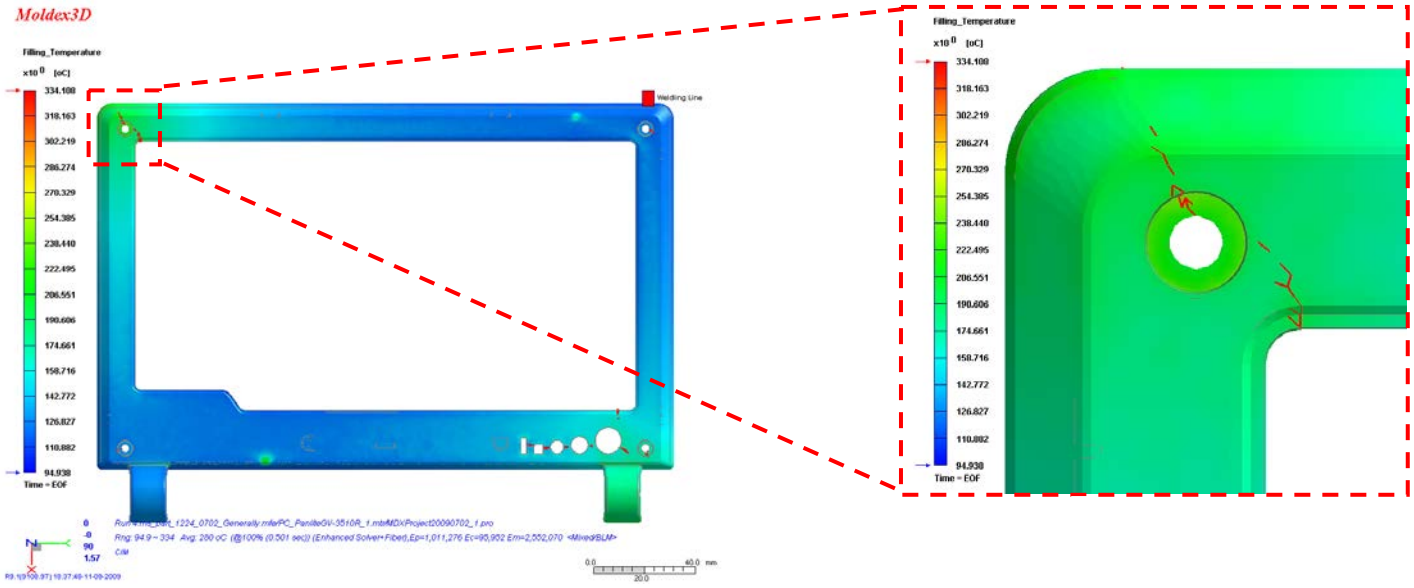


0.5s (end of filling)

Cross-sectional Mold temperature variation of IHM (heating to 150°C)

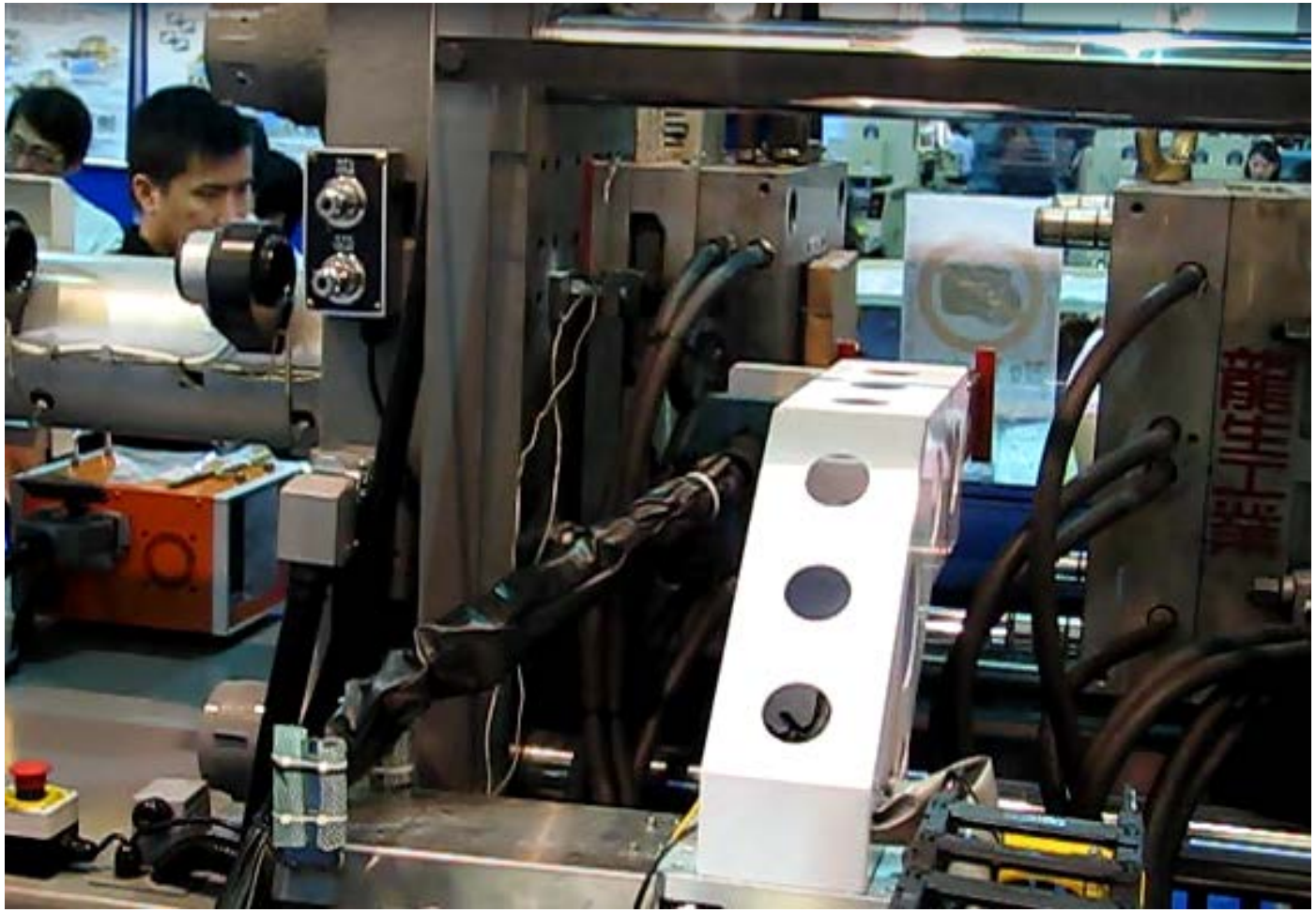


Weldline temperature



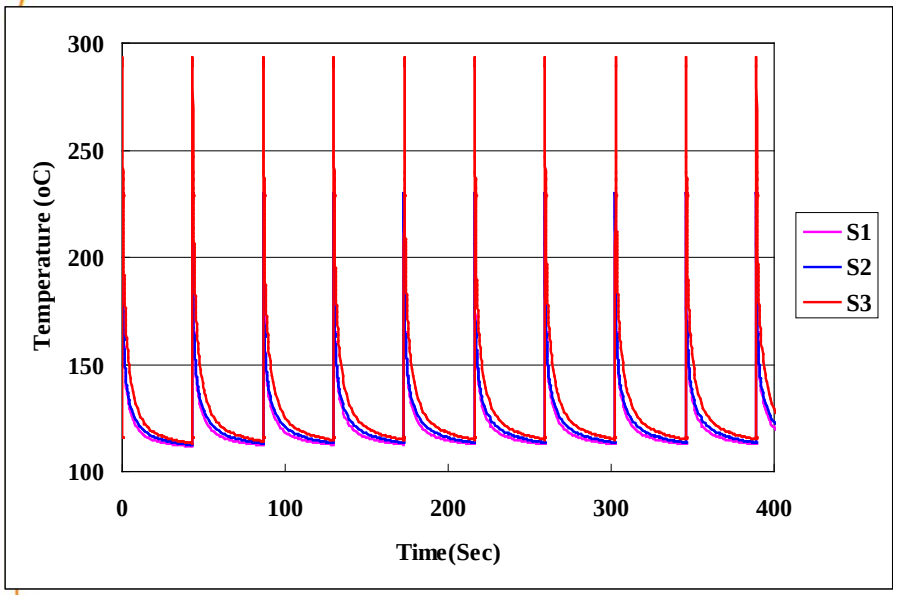
	Weldline temperature
CIM	170°C ~200°C
RHCM	190°C ~220°C
IHM	205°C ~235°C
E-mold	210°C ~240°C

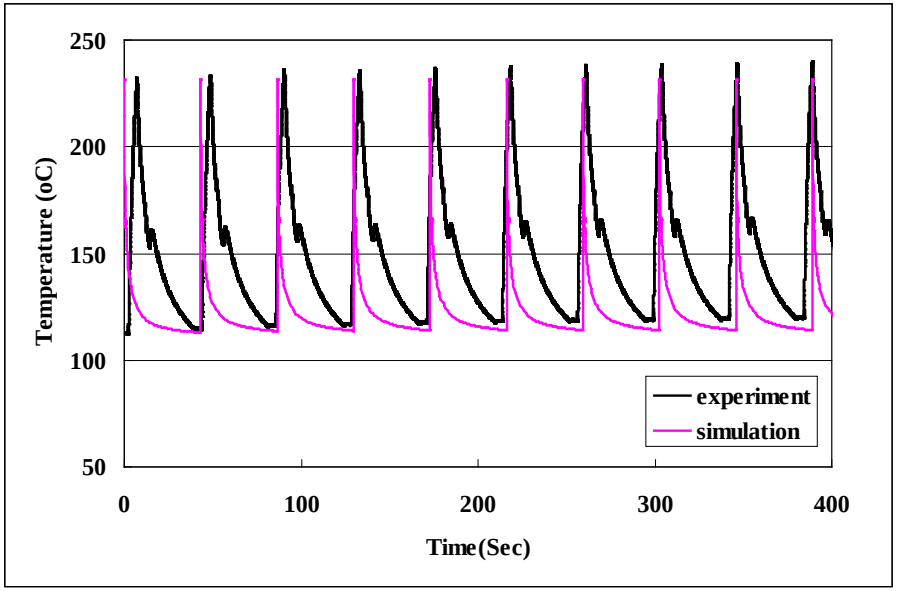
Flow Chart for Experimental Investigation Based on IHM



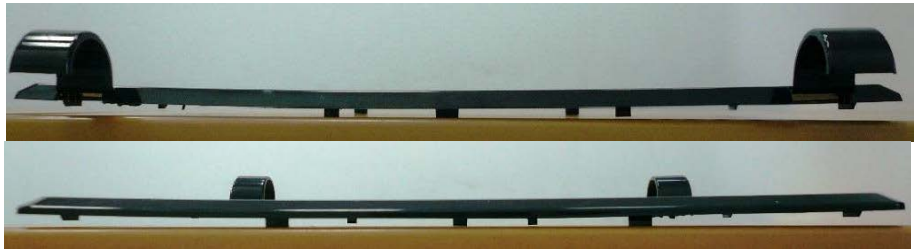
Source: Dragonjet Co., Taiwan

Temperature comparison

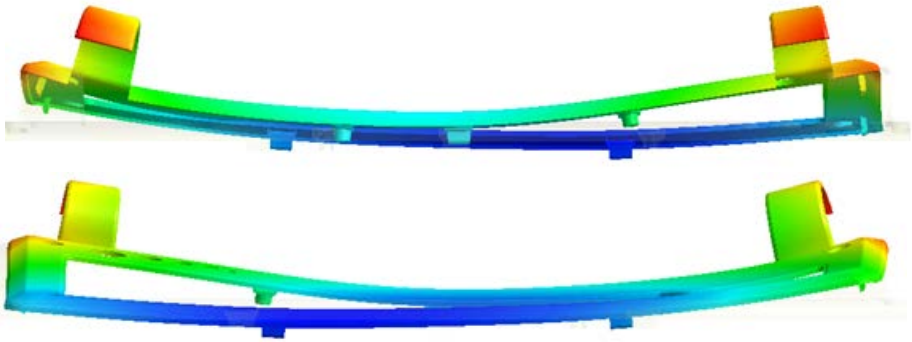




The displacement measurement based on IHM

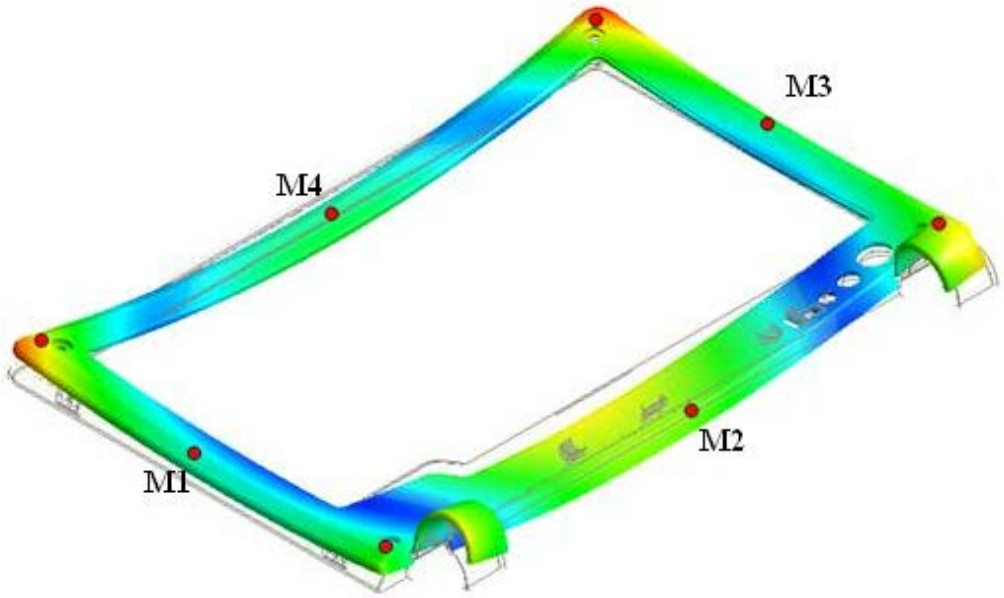


Experimental result



Simulation result

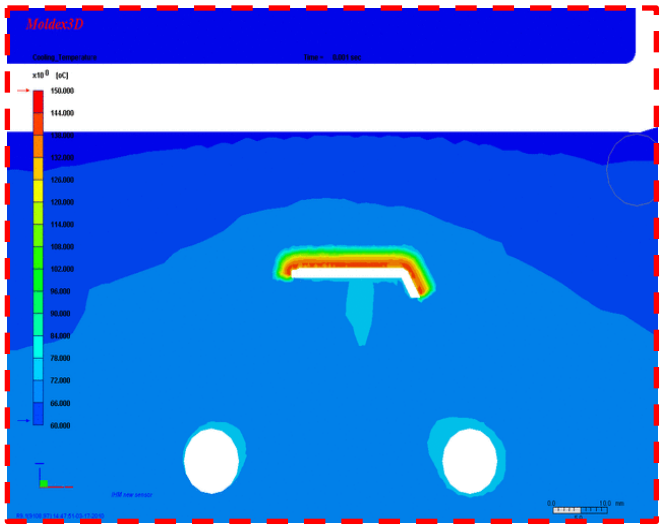
The location of measure nodes

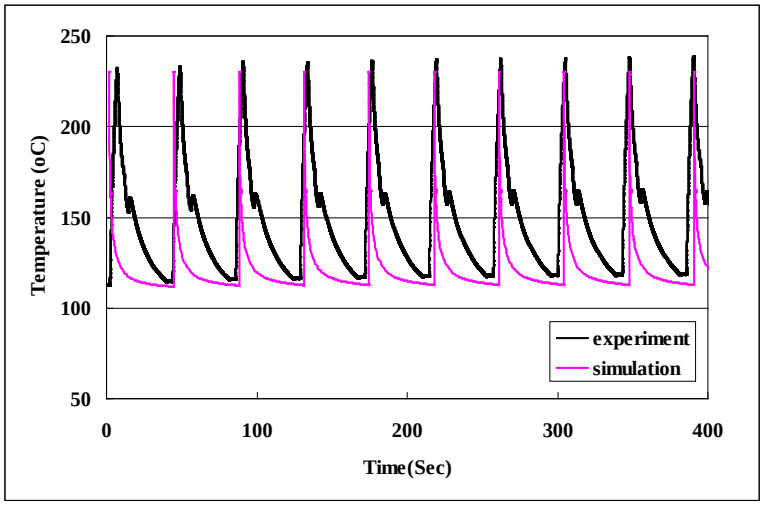


displacement(mm)	M1	M2	M3	M4
experiment	0.2	1.4	0.2	0.8
simulation	0.2	1.29	0.17	0.66

Benefits of Moldx3D

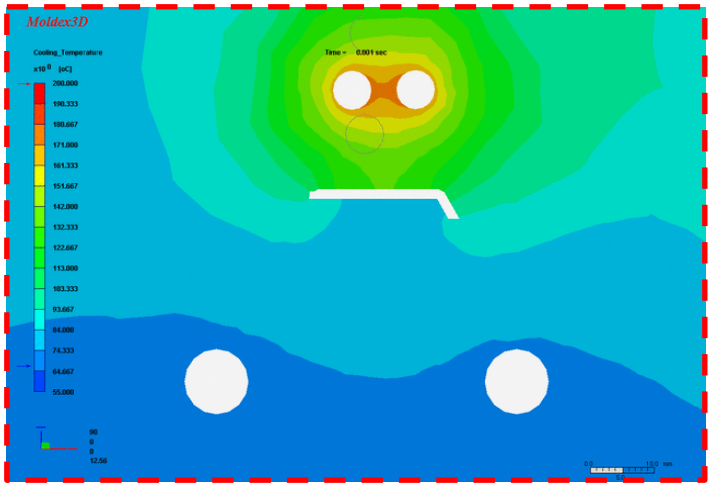
- To visualize the complicated RHCM and IHM system
  - Understanding mechanism for RHCM and IHM
  - Design validation before real mold fabrication
  - Cost reduced by 1/3

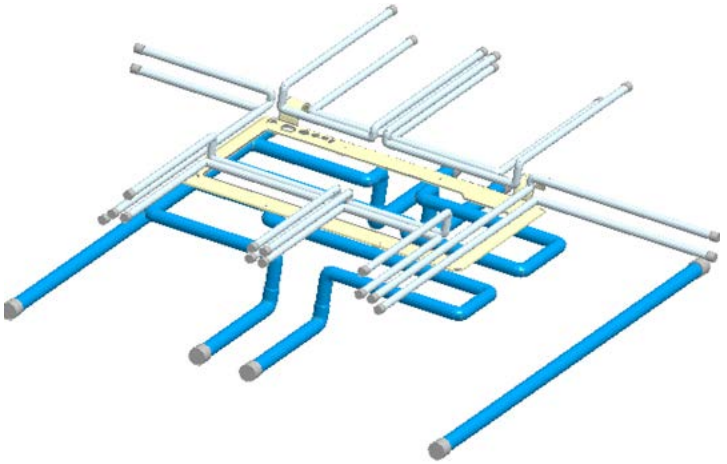




Conclusion

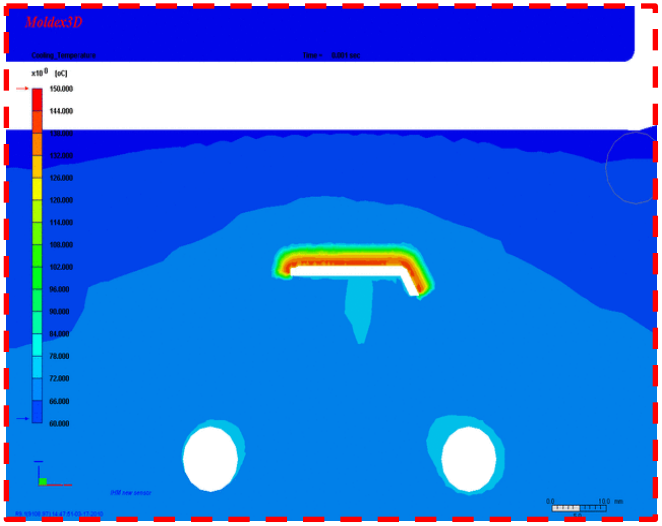
- In injection molding process
  - Mold temperature control is one of the good solutions
    - Conventional cooling channel
    - Various methods, such as RHCM, IHM, IR heating, …
  - What happens inside the mold system?
    - 3D Transient Cool Analysis technology can help us

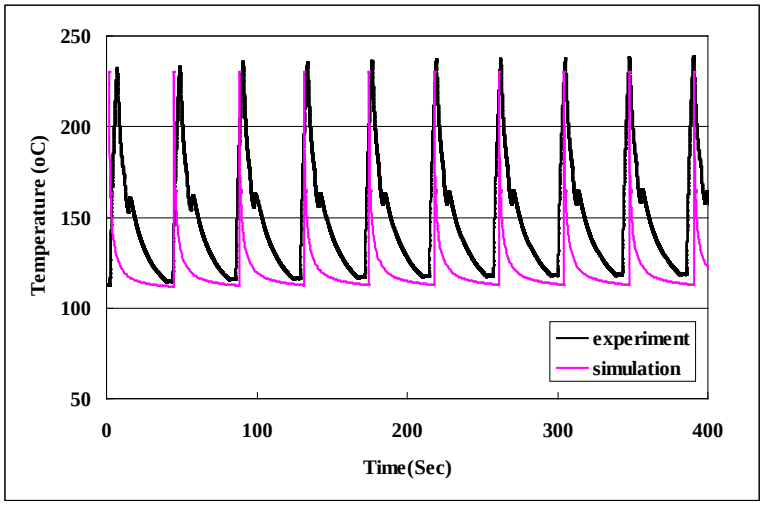




Conclusion

> Real experience,
  - Moldex3D can help to enhance
    - Cost down
    - Capability
    - Competition





Q and A?

Moldex3D

Thank you for your attention!